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Minimum Operational Performance
Standards (MOPS)
For Airborne Separation Assurance System (ASAS)

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains Minimum Operational Performance Standards (MOPS) for the Airborne Separation Assurance System (ASAS). These standards specify system characteristics that should be useful to designers, manufacturers, installers and users of the equipment.

These MOPS for ASAS contain requirements for processing and display of traffic and Ownship information for use by the flight crew in performing airborne applications.

Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operation. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

Section 1 of this document provides information needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment operations and operation goals, as envisioned by the members of Special Committee 186, and establishes the basis for the standards stated in Sections 2 through 3. Definitions and assumptions essential to proper understanding of this document are also provided in this section.

Section 2 contains the Minimum Performance Standards for the equipment. These standards specify the required performance under standard environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.

Section 3 describes the performance required of installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational performance characteristics for equipment installations and defines conditions that will assure the equipment user that operations can be conducted safely and reliably in the expected operational environment.

This document considers functional requirements consisting of: airborne surveillance and separation assurance processing (ASSAP), and cockpit display of traffic information (CDTI) as described in the ASA MASPS, DO-289 Operational performance standards for functions or components that refer to equipment capabilities that exceed the stated minimum requirements are identified as optional features.

The word "function" as used in this document includes all components and units necessary for the system to properly perform its intended function(s). For example, the "function" may be implemented in hardware or software, as appropriate, and the function

may be partitioned within the hardware and software as is most convenient for a particular implementation.

If the functional implementation includes a computer software package, the guidelines contained in RTCA Document No. DO-178B, *Software Consideration in Airborne Systems and Equipment Certification*, should be considered.

1.2 System Overview

The systems supporting both ground based and aircraft-to-aircraft applications consist of ground systems and the Aircraft Surveillance Applications (ASA) system (Figure 1-1). The ASA system consists of five major subsystems, of which this ASAS MOPS specifies two subsystems. The five subsystems of ASA are: a surveillance transmit processing subsystem (STP), a surveillance subsystem (including ADS-B and TIS-B transmit and receive), a surveillance data processing subsystem, Airborne Surveillance and Separation Assurance Processing (ASSAP), and a display subsystem Cockpit Display of Traffic Information (CDTI). ASA also interfaces with other aircraft systems. Figure 1-1 provides an overview of the system architecture and depicts the interfaces between functional elements for an ASA aircraft participant. Note that the ADS-B transmit and receive subsystems are specified in RTCA DO-260() and RTCA DO-282() for the 1090 and UAT systems, respectively and the Surveillance Transmit Processing subsystem is specified in RTCA DO-302.
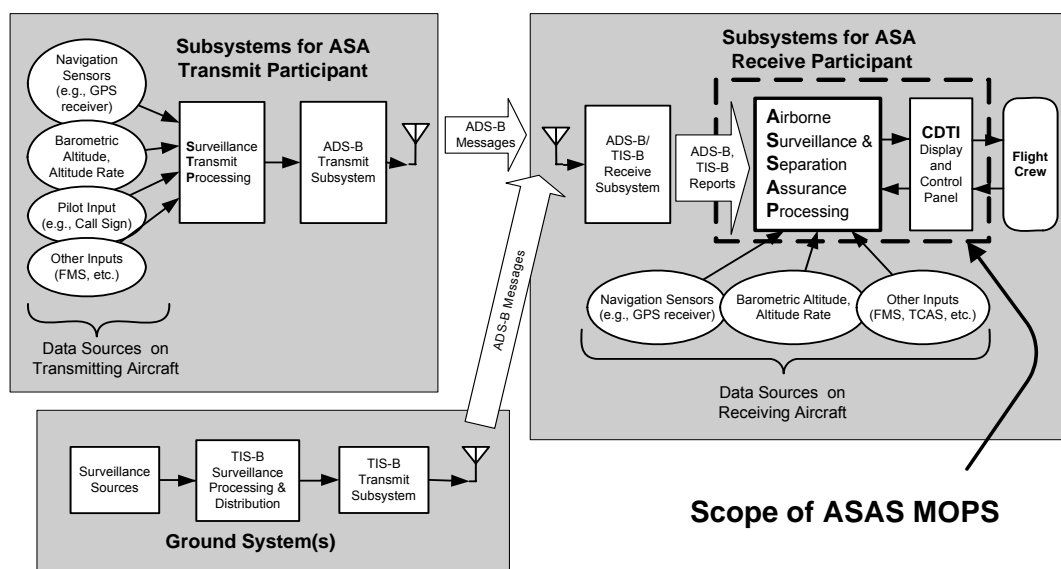
Figure 1-1 Overview of ASA Architecture

The Surveillance Transmit Processing (STP) subsystem prepares the required surveillance information from on-board aircraft sensors for the ADS-B Transmit Subsystem. Traffic Information Service Broadcast (TIS-B) messages are processed to include similar surveillance information obtained through ground surveillance systems. TIS-B messages are broadcast by the TIS-B Transmit Subsystem. ADS-B Rebroadcast

(ADS-R) provides traffic information to equipped aircraft based on ADS-B transmission from aircraft on independent data links (1090ES and UAT).

ADS-B, TIS-B and ADS-R messages are received by the ADS-B/TIS-B Receive Subsystem at the receiving ASA Aircraft/Vehicle (A/V). The ADS-B/TIS-B Receive Subsystem processes these messages and provides ADS-B, TIS-B, and ADS-R traffic reports to ASSAP.

The blocks in Figure 1-1 labeled ASSAP and CDTI collectively are referred to as ASAS and are the scope of this document. ASSAP is the processing subsystem that accepts surveillance inputs, e.g., ADS-B reports, performs surveillance processing to provide reports and tracks, and performs application-specific separation assurance processing. Surveillance reports, tracks, and any application-specific alerts or guidance are output by ASSAP to the CDTI function. ASSAP surveillance processing consists of track processing and correlation of ADS-B, TIS-B, ADS-R, and TCAS reports. In addition to these interfaces and depending on the actual ASA application, ASSAP may interface to the Flight Management System (FMS) and/or the Flight Control (FC) systems for flight path changes, speed commands, etc. ASSAP also interfaces with:

- The ADS-B transmitter and receiver to support transmission of application-specific messages, etc.

- Inputs from the Ownship navigation system to obtain state information on own aircraft, and

- TCAS (TCAS I and TCAS II), for combined displays. Also, some applications (e.g., CD and ACM) may suppress alerts in the event that TCAS advisories are present; other applications (e.g., ICSPA) may suppress TCAS advisories on specific targets.

The CDTI subsystem shown in Figure 1-1 includes the actual display media and the necessary controls to interface with the flight crew. Thus the CDTI consists of a display and control panel. The control panel may be a dedicated CDTI control panel or it may be incorporated into another control, e.g., multifunction display unit (MCDU). Similarly, the CDTI display may also be a stand-alone display (dedicated display) or the CDTI information may be present on an existing display (e.g., multi-function display)

1.3   Operational Application(s)

The standards defined in this version of the ASAS MOPS have been scoped to support the five initial applications defined in the ASA MASPS (DO-289) which are as follows:

- Enhanced Visual Acquisition (EVAcq)

- Conflict Detection (CD)

- Airport Surface Situational Awareness (ASSA)

- Final Approach and Runway Occupancy Awareness (FAROA)

- Enhanced Visual Approach (EVApp)

A description of each of the supported applications follows:

Enhanced Visual Acquisition: Cockpit Display of Traffic Information (CDTI) provides traffic information to assist the flight crew in visually acquiring traffic out the window. The CDTI can be used to initially acquire traffic (that the pilot might not have known about otherwise) or as a supplement to an ATC traffic advisory. This application is expected to improve both safety and efficiency by provided the flight crew basic traffic awareness leading to better maneuver decisions.

Conflict Detection (CD): The CDTI is used to alert the flight crew of nearby traffic. The alert may prompt the flight crew to exercise see-and-avoid procedures or to contact ATC. Conflict avoidance maneuvers are not suggested by this application. This application is expected to improve safety by alerting the flight crew about potential conflicting traffic and by providing information that can aid the flight crew in making visual, out-the-window maneuver decisions.

Airport Surface Situational Awareness (ASSA), and Final Approach and Runway Occupancy Awareness (FAROA): In these applications, the CDTI is used by the flight crew to make taxiing decisions based on traffic and to determine runway and final approach occupancy. The applications will support the flight crew in making decisions about taxiing, takeoff and landing. They are expected to increase efficiency of operations on the airport surface and reduce runway incursions and collisions. Enhanced Visual Approach: The CDTI is used to assist the flight crew in acquiring and maintaining visual contact during visual approaches. The CDTI is also used in conjunction with visual, out-the-window contact to follow the lead aircraft during the approach, i.e., during conduct of the visual separation task. The application is expected to improve both the safety and the performance of visual approaches. It could allow for the continuation of visual approaches when they otherwise would have to be suspended due to the difficulty of visually acquiring and tracking the other aircraft.

Enhanced Visual Approach (EVApp): The Enhanced Visual Approach (EVApp) application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft more effectively. The complete application description is included in Appendix G. EVAcq is considered to be a coupled application, as it applies only to the preceding aircraft.

1.4 Intended Function

The intended function of equipment built to the specifications in this MOPS is to perform the processing and displays that support the requirements of the applications described in section 1.3. The equipment will perform its intended function(s), as defined by this document and the manufacturer and its proper use will not create a hazard to other users of the National Airspace System.

1.5 Assumptions

1.5.1 Own-ship Position

It assumed that ASSAP will compensate for latency in own-ship position. Ownship position data willshould be delivered to ASSAP such that the uncompensatedable latency is less than 6200 ms. GPS sensors compliant with ARINC 743A-4 and RNP FMS compliant with ARINC 702A Supplement 3 are examples of acceptable position sources.

1.5.2 ADS-B Reports

All ADS-B Reports generated by the ADS-B link receiver are subject to track initiation and update criteria as defined by the appropriate link MOPS (DO-260() and DO-282()). Therefore, ASAP is required to track all reports received from the ADS-B receiver. ASSAP uses state vector and mode status reports as defined in DO-242().

1.5.3 Dual Link Transmissions

ASSAP does not address aircraft configurations that include transmissions with more than one link. Dual link receivers may receive both ADS-B and ADS-R sources, in this case, ADS-R should be disregarded.

1.5.4 1090ES Duplicate Address

1090ES receiving subsystems providing reports to ASSAP will detect duplicate addresses and will not forward reports for distinct tracks with the same addressand under certain conditions will reject position reports from targets with duplicate addresses. However, - ASSAP will not detect or resolve misassociated information (e.g., Mode Status and velocity) as a result of a duplicate addresses.

1.5.5 24 Bit Mode S Address with TCAS Track Updates

The ASSAP example architecture and test scenarios assume that TCAS will provide Mode S address (when available) in TCAS track updates to ASSAP. Existing interface documents (i.e., ARINC 735A) do not support this assumption. It may still be possible to meet ASSAP requirements without the Mode S address.

1.5.6 Dual Link Receiver

ASSAP requirements and test scenarios and the reference system design in Appendix C do not address the case of dual link receivers on the ownship.

1.5.7 TIS-B Service Status

Current plans for the ground infrastructure include support for a TIS-B Service Status mechanism that is oriented to individual TIS-B customers. Initially, this will be provided for TIS-B customers that both transmit and receive on the UAT data link. While no

requirements appear in this document related to avionics processing of the TIS-B service status, Appendix H~~22~~ provides information on the approach and an example implementation for manufacturers who wish to support a TIS-B service status annunciation.

1.5.8   **TIS-B On Airport Surface**

As of this revision of the ASAS MOPS, ASSAP requirements and test scenarios do not specifically address correlation between TIS-B and other sources (ADS-B, ADS-R) or ownship for the airport surface. The geometric filters used for determining correlation would be unable to function properly in the dense target environment that could exist on the surface, potentially resulting in a higher rate of ghosting between ADS-B and TIS-B targets and possibly ghosting own-ship as well.

At airports where TIS-B is supported on the airport surface, the following factors should be considered:

Reliable correlation of a detection from a surface surveillance system (i.e., Multilat) may only be possible via the 24 bit ICAO address available in ADS-B and from the Mode S transponder. Likewise, reliable TIS-B/ADS-B correlation may not be possible on ADS-B equipped aircraft with ATCRBS transponders. Users should expect ghost targets or shadows of ownship for aircraft equipped this way. On the surface, ASSAP will only suppress a TIS-B track (from the CDTI) if it has the same track ID as ownship.

The TIS-B transition between the surface surveillance and airborne surveillance may not be seamless due to the fact that the service provider may use independent trackers for each. As a result, spurious targets may appear for one or two update intervals during the transition (e.g., in the region between liftoff/touchdown and 500 AGL)[j1]

1.5.9   **24 Bit Addresses**

A Single 24 Bit Address will be used onboard an aircraft across all links.

1.6   **Test Procedures**

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirement. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The order of tests specified suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2 shall have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.

a. Environmental Tests

Environmental test requirements are specified in Subsections 2.4 (ASSAP) and 2.5 (CDTI). The procedures and their associated limits are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations.

Unless otherwise specified, the environmental conditions and test procedures contained in RTCA Document No. DO-160C, *Environmental Conditions and Test Procedures for Airborne Equipment*, will be used to demonstrate equipment compliance.

b. Bench Tests

Bench test procedures are specified in Subsection 2.4. These tests provide a laboratory means of demonstrating compliance with the requirements of Subsection 2.2. Test results may be used by equipment manufacturers as design guidance, for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

c. Installed Equipment Tests

The installed equipment test procedures and their associated limits are specified in Section 3. Although bench and environmental test procedures are not included in the installed equipment test, their successful completion is a precondition to completion of the installed test. In certain instances, however, installed equipment test may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

1. With the aircraft on the ground and using simulated or operational system inputs.

2. With the aircraft in flight using operational system inputs appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the intended operational environment.

d. Operational Tests

The operational tests are specified in Section 4. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

2　EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1　General Requirements

General equipment requirements need not be tested in the test procedure subsection. If a requirement needs to be tested, it is not a general requirement and should be included in section 2.2*.*

2.1.1　Airworthiness

In the design and manufacture of the equipment, the manufacturer **shall** (R2.1) provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2　Intended Function

The equipment **shall** (R2.2) perform its intended function(s), as defined by the manufacturer, and its proper use **shall** (R2.3) not create a hazard to other users of the National Airspace System.

2.1.3　Federal Communications Commission Rules

All equipment **shall** (R2.4) comply with the applicable rules of the Federal Communication Commission.

2.1.4　Fire Protection

All materials used **shall** (R2.5) be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note:　One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.

2.1.5　Operation of Controls

The equipment **shall** (R2.6) be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the reliability of the equipment or operation of the aircraft.

2.1.6　Accessibility of Controls

Controls that do not require adjustment during flight **shall** (R2.7) not be readily accessible to flight personnel.

2.1.7 Effects of Test

The equipment **shall** (R2.8) [belongs in subsection 2.2.x] be designed so that the application of specified test procedures **shall** [belongs in subsection 2.2.x] not be detrimental to equipment performance following the application of the tests, except as specifically allowed.

2.1.8 Design Assurance

Reference back to the ASA MASPS for design assurance requirements. This paragraph will discuss the appropriate design assurance level(s) that would be expected as a result of the function definitions and failure categorization(s) contained in Section 1 of the document. This should be based upon the criteria of AC 23.1309 and 25.1309-1b. This paragraph should address both misleading information and the loss of the function. MOPS should point to the latest revision of the RTCA DO-178() and DO-254() document as a method of establishing the appropriate software levels. A specific software level should not be established in the MOPS since the definitions of the levels could change in RTCA DO-178() and DO-254 after the MOPS is issued. The MOPS under development should also point to any hardware or system design assurance standards that are in effect at the time or writing (i.e., SAE ARP-4754).[j2]

All applications in this document are considered to be of minor criticality per AC 25-1309 and AC 23-1309 (see DO-289 for the analyses justifying this criticality). The hardware and software **shall** (R2.9) be designed and developed such that the probability of providing misleading information (MI) and the probability of loss of function at interface F1 in Figure 1-1 are acceptable based on the overall allocated system integrity and continuity requirements, respectively. These requirements apply when the equipment is in its installed configuration for the most stringent operation supported. To demonstrate compliance, it will be necessary to conduct a safety assessment to evaluate the system's implementation against known failure conditions. This safety assessment should be based upon the guidance of AC 23.1309-1() for Part 23 aircraft, AC 25.1309-1() for Part 25 aircraft, AC 27-1() for normal category rotorcraft, and AC 29-2() for transport category rotorcraft.

My guess is this could be generalized for both ASSAP and CDTI. Need to check with them.

2.2 Airborne Surveillance and Separation Assurance Processing (ASSAP) Subsystem Requirements

2.2.1 Introduction

Airborne Surveillance and Separation Assurance Processing (ASSAP) is a function that receives surveillance reports on other aircraft/vehicles from multiple sources and derives traffic surveillance and application-specific information for visual and / or aural display to the CDTI for the flight crew. ASSAP receives ADS-B / ADS-R / TIS-B reports that are assembled by the ADS-B/TIS-B Receive subsystem from corresponding ADS-B /

ADS-R / TIS-B messages. ASSAP surveillance processing consists of correlation, possible data fusion and track processing of ADS-B, TIS-B and TCAS traffic reports. ASSAP application processing provides the application-specific processing of all ASA applications.

Note: Future ASAS MOPS that include other applications may also provide guidance information to the CDTI.

It is recognized that manufacturers may implement separate ASSAP and CDTI functions, or a single integrated function that satisfies the requirements of both the ASSAP and CTDI functions. The ASSAP requirements have been written to allow this implementation flexibility. For the purposes of these MOPS and the following sections, the phrase "ASSAP equipment" refers to the equipment providing the ASSAP functionality and does not imply any implementation or design.

This section defines the general requirements for the ASSAP function. The ASSAP subsystem provides the necessary surveillance and application-specific processing of ASA. ASSAP also maintains the interface with the CDTI Display and Control Panel subsystem. The combination of the aircraft data sources on the receiving aircraft, the ADS-B/TIS-B Receive Subsystem and the ASSAP function make up the ASA Receive system. This is illustrated in Figure 2-1.
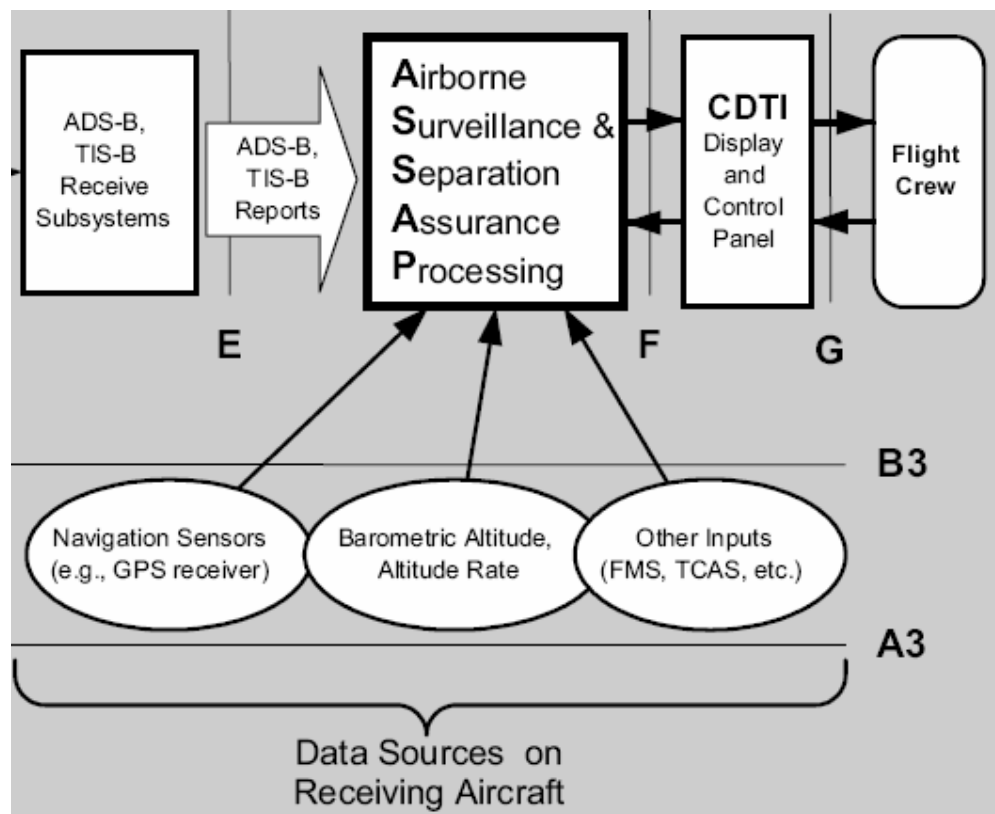
Figure 2-1 Subsystems for ASA Receive Participant

The entire ASA Receive System is responsible for the reception and processing of own-ship data as well as the reception of ADS-B and TIS-B messages from other A/Vs and ground systems for the purpose of supporting ASA application processing and providing aural and visual ASA-specific display information to the flight crew. This ASSAP MOPS specifies requirements defined in the following sections and applies specifically to the ASSAP functionality occurring between interfaces E and G as illustrated in Figure 2-1.

Section 2.2 is broken into two major sub-sections: functional requirements and performance requirements. These requirements sections are further broken down into Input/Output, Surveillance Processing, Application Processing and Performance Monitoring. ASSAP surveillance requirements include Track initiation, update, deletion, extrapolation and prediction; Track merging and splitting; Inter-source correlation (TIS-B & ADS-B; TCAS & others; TIS-B & Own-ship) and Best selection of data sources. A functional representation of the ASSAP surveillance processing is shown in Figure 2-2. ASSAP application requirements are broken down into common requirements (such as Track Prioritization) and application specific requirements for each of the ASA applications (Enhanced Visual Acquisition, ASSA/FAROA, CD, Enhanced Visual Approach, etc.)
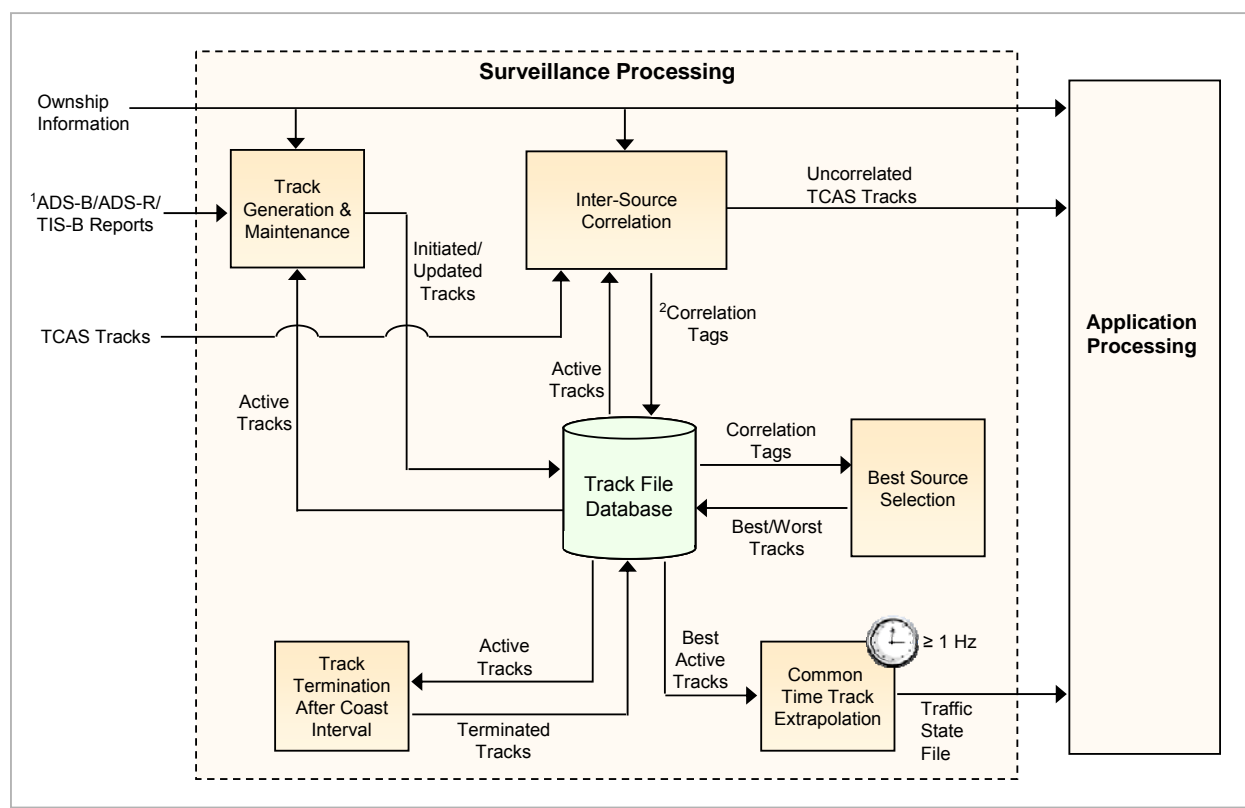
Figure 2-2 ASSAP Surveillance Processing Functional Flow Block Diagram

The ASSAP function may be implemented in stand-alone equipment, integrated with the ADS-B Receive equipment or integrated with other systems. The ASSAP requirements remain applicable when integrated in these alternative implementations.

2.2.2 ASSAP Input / Output Requirements

This section summarizes ASSAP input / output interfaces to other subsystems as shown below.
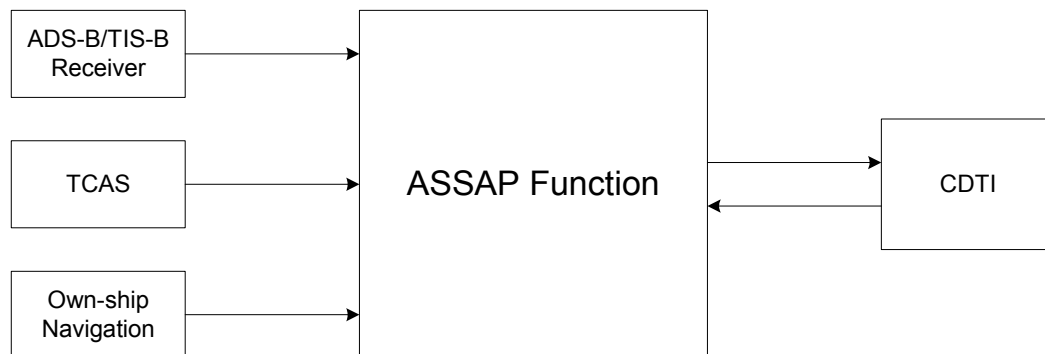
Figure 2-3 Summary of ASSAP Input / Output Interfaces

The following subsections contain basic ASSAP input / output requirements that are required to support the EV Acquisition application as a minimum. The CD, ASSA, FAROA, and EV Approach applications are optional; but when they are implemented, the requirements designated for these applications must be met.

2.2.2.1 ASSAP Input Requirements from ADS-B/TIS-B Receiver

This section defines the traffic state data and traffic ID/status data supplied to the ASSAP function from the ADS-B/TIS-B receiver. Reception of various data links will be possible which may include 1090 MHz Extended Squitter, UAT, or VDL-4. The requirements specified in this section are meant to define the minimum required traffic data set needed to support ASSAP. Specific ADS-B/TIS-B receiver and data link requirements can be found in the MOPS for 1090 MHz (RTCA DO-260A), UAT (RTCA DO-282), and VDL-4 SARPS (ED-108).

2.2.2.1.1 Traffic State ~~Data~~Vector Report Input Requirements

Traffic state data is information describing the aircraft state that generally changes rapidly (e.g., position, altitude, and velocity). The following traffic state data is required for ASSAP in accordance with RTCA DO-260()A, RTCA DO-282(), and ED-108().

1. The ASSAP function **shall** receive the Time of Applicability (TOA) of the received traffic state data from the ADS-B/TIS-B receiver.

Note: The Time of Applicability is based on the time of message reception but varies by the type of data link.

2. The ASSAP function **shall** receive the Horizontal Position ~~based on WGS-84~~ latitude/longitude from the ADS-B/TIS-B receiver.

3. The ASSAP function **shall** receive the Horizontal Velocity from the ADS-B/TIS-B receiver when available.

Note: The magnitude of the Horizontal Velocity can also be used for ground speed. The Cartesian coordinates of velocity (e.g., north and east velocity components) can also be used to calculate true track angle but should be considered invalid per Section 2.2.2.5.1.12 Traffic Track Angle.

4. For the ASSA and FAROA applications, the ASSAP function **shall** receive the Ground Speed when on Surface from the ADS-B/TIS-B receiver when available.

5. The ASSAP function **shall** receive the Pressure Altitude from the ADS-B/TIS-B receiver when available.

6. The ASSAP function **shall** receive the ~~WGS-84~~ Height above Ellipsoid (HAE), Geometric Altitude from the ADS-B/TIS-B receiver when available.

7. The ASSAP function **shall** receive the Vertical Rate from the ADS-B/TIS-B receiver when available.

8. The ASSAP function **shall** receive the Vertical Rate Type (i.e., Geometric or Barometric) from the ADS-B/TIS-B receiver when available.

9. The ASSAP function **shall** receive the Heading when on Surface (i.e., true or magnetic heading) from the ADS-B/TIS-B receiver when available.

10. For ADS-B/TIS-B traffic reports based on DO-260A and later, ~~Version 1~~ and DO-282()~~A~~, the ASSAP function **shall** receive the Navigation Integrity Category (NIC) from the ADS-B/TIS-B receiver when available.

11. The ASSAP function **shall** receive the Air/Ground State from the ADS-B/TIS-B receiver when available.

Note: The ADS-B/TIS-B receiver usually determines the traffic air/ground state based on receiving either surface position reports (ground state) or airborne position reports (air state).

2.2.2.1.2   Traffic ID/Status Data **Report** Input Requirements

Traffic ID/status data is information about the aircraft that generally changes less frequently than the traffic state data (e.g., Flight ID and Participant Address). The

following traffic ID/status data is required for ASSAP in accordance with RTCA DO-260A, RTCA DO-282, and ED-108.

1. The ASSAP function **shall** receive the Flight ID (up to 8 alphanumeric characters in length) from the ADS-B/TIS-B receiver when available.

2. The ASSAP function **shall** receive the Participant Address from the ADS-B/TIS-B receiver.

3. The ASSAP function **shall** receive the Participant Address Qualifier (indicating whether the Participant Address is a 24-bit ICAO address or another kind of address) from the ADS-B/TIS-B receiver when available.

4. The ASSAP function **shall** receive the Emitter Category (e.g., light, small aircraft, rotorcraft, etc.) from the ADS-B/TIS-B receiver when available.

5. (Optional) The ASSAP function **shall** receive the A/V Length and Width Code from the ADS-B/TIS-B receiver when available.

6. For ADS-B traffic reports based on DO-260 Version 0, the ASSAP function **shall** receive the Navigation Uncertainty Category for Position (NUC_P) from the ADS-B receiver when available.

7. For ADS-B traffic reports based on DO-260 Version 0, the ASSAP function **shall** receive the Navigation Uncertainty Category for Rate (NUC_R) from the ADS-B receiver when available.

8. For ADS-B/TIS-B traffic reports based on DO-260A Version 1 and DO-282A, the ASSAP function **shall** receive the Navigational Accuracy Category for Position (NAC_P) from the ADS-B/TIS-B receiver when available.

9. For ADS-B/TIS-B traffic reports based on DO-260A Version 1 and DO-282A, the ASSAP function **shall** receive the Navigational Accuracy Category for Velocity (NAC_V) from the ADS-B/TIS-B receiver when available.

10. For ADS-B/TIS-B traffic reports based on DO-260A Version 1 and DO-282A, the ASSAP function **shall** receive the Surveillance Integrity Level (SIL) from the ADS-B/TIS-B receiver when available.

2.2.2.2   **ASSAP Input Requirements from TCAS**

The following TCAS traffic information is required for systems integrated with TCAS.

1. The ASSAP function **shall** be capable of receiving a traffic capacity of at least 30 tracks from TCAS.

Note: A traffic capacity of 30 tracks is based on supporting the TCAS II tracking capacity for active surveillance (Reference RTCA DO-185A TCAS II MOPS

Section 2.2.4.6.1 Surveillance Target Track Capacity). If TCAS provides more tracks than ASSAP's traffic capacity, then ASSAP should accept the highest priority tracks. TCAS usually provides all tracks in the order of priority.

2. The ASSAP function **shall** receive the TCAS Report Time from TCAS if available.

3. The ASSAP function **shall** receive the TCAS Track ID from TCAS.

Note: The TCAS Track ID is a unique identifier that identifies the traffic for which data is being provided.

4. The ASSAP function **shall** receive the Mode S Address from TCAS when available.

5. The ASSAP function **shall** receive the Range from TCAS.

Note: ASSAP designers must consider in ~~its~~ their implementation that the type of range from TCAS may be represented as either slant or horizontal range relative to own-ship's position.

6. The ASSAP function **shall** receive the Bearing from TCAS when available.

7. The ASSAP function **shall** receive the Altitude from TCAS when available.

8. The ASSAP function **shall** receive the Altitude Rate from TCAS when available.

9. The ASSAP function **shall** receive the TCAS Alert Status (i.e., no threat, proximity traffic, traffic advisory, resolution advisory) from TCAS when available.

10. The ASSAP function **shall** receive the TCAS Vertical Sense from TCAS when available.

Note: The TCAS Vertical Sense is an indication whether the traffic vertical direction is climbing, descending, or level.

2.2.2.3   ASSAP Input Requirements from Own-ship Navigation

This section defines the own-ship state data and own-ship quality data supplied to the ASSAP function from the own-ship navigation sources.

~~The received own-ship navigation data sources~~ **~~shall~~** ~~be the same as the data sources transmitted out by the ADS-B transmitter per RTCA DO-302 STP MOPS.~~If different ownship position sources are used by ASSAP and the CDTI, both sources **shall** meet the requirements defined in Table 2-2. [j3]

The ASSAP function **shall** use the same data source for all the horizontal position and navigation data which includes latitude, longitude, horizontal integrity data (HIL/RNP/ANP), N/S velocity, E/W velocity. Mixing of data (e.g. use latitude from GNSS and longitude from FMS) is prohibited between the possible input data sources. If

the position data from a navigation source is not valid, then no data from that navigation source **shall** be accepted.

2.2.2.3.1   Own-ship State Data Input Requirements

Own-ship state data is information describing the own-ship state that generally changes rapidly (e.g., position, altitude, and velocity). The following own-ship state data is required for ASSAP.

1. The ASSAP function **shall** receive the Time of Applicability (TOA) of the received own-ship state data from the own-ship navigation sources.

Note: The Time of Applicability is based on the time of data reception.

2. The ASSAP function **shall** receive the Horizontal Position based on ~~WGS-84~~ latitude/longitude from the own-ship navigation sources.

Note: horizontal position inputs must be in WGS-84 coordinates.

3. The ASSAP function **shall** receive the Horizontal Velocity from the own-ship navigation sources when available.

Note: The magnitude of the Horizontal Velocity can also be used for ground speed. The Cartesian coordinates of velocity (e.g., north and east velocity components) can also be used to calculate true track angle but should be considered invalid per Section 2.2.2.5.2.3 Own-ship Track Angle.

4. The ASSAP function **shall** receive the True Track Angle from the own-ship navigation sources when available.

Note: Based on the type of own-ship navigation source, the accuracy of its true track angle should be considered below some ground speed threshold.

5. For the ASSA and FAROA applications, the ASSAP function **shall** receive the Ground Speed from the own-ship navigation sources when available.

6. The ASSAP function **shall** receive the Pressure Altitude from the own-ship navigation sources when available. The pressure altitude source **shall** be the same source as that being used by the transponder for transmission.

7. The ASSAP function **shall** receive the ~~WGS-84~~ Height above Ellipsoid (HAE) Geometric Altitude from the own-ship navigation sources when available.

Note: HAE inputs must be in WGS-84 coordinates.

8. The ASSAP function **shall** receive the Pressure Altitude Rate from the own-ship navigation sources when available.

9. The ASSAP function **shall** receive the ~~WGS-84 Height above Ellipsoid (HAE)~~ Geometric Altitude Rate from the own-ship navigation sources when available.

10. The ASSAP function **shall** receive the Heading when on Surface (i.e., true or magnetic heading) from the own-ship navigation sources when available.

11. The ASSAP function **shall** receive the Participant Address from the own-ship navigation sources when available.

12. (Optional) The ASSAP function **shall** receive the A/V Length and Width Code from own-ship sources when available.

2.2.2.3.2 Own-ship Quality Data Input Requirements

Own-ship quality data is very similar to traffic quality data; however, as the information comes directly from the own-ship navigation sensor it is not yet categorized into NIC, NAC and SIL values. ~~The ASSAP function will receive the data as it is output from the STP subsystem per RTCA DO-302 STP MOPS.~~ The following own-ship quality data is required for ASSAP.

1. The received own-ship quality data **shall** be based on the state data quality as determined per RTCA DO-302 STP MOPS.

Note: The state data quality is determined based on the type of source that is available and also takes into account limiting factors. See the STP MOPS for the definitions of the variables referenced in the following items.

2. ~~The ASSAP function **shall** receive the Participant Address from the own-ship navigation sources when available.~~

3. ~~(Optional) The ASSAP function **shall** receive the A/V Length and Width Code from own-ship sources when available.~~

4.2. The ASSAP function **shall** either derive~~receive~~ the Horizontal Position Accuracy ($HFOM_{STP}$) from the own-ship navigation sources when available or receive the Horizontal Position Accuracy ($HFOM_{STP}$) from STP~~from the own-ship navigation sources when available~~ when available.

5.3. The ASSAP function **shall** receive the Vertical Position Accuracy ($VFOM_{STP}$) from the own-ship navigation sources when available.

6.4. The ASSAP function **shall** receive the Horizontal Velocity Accuracy ($HFOM_{RSTP}$) from the own-ship navigation sources when available.

7.5. The ASSAP function **shall** receive the Vertical Velocity Accuracy ($VFOM_{RSTP}$) from the own-ship navigation sources when available.

8.6. The ASSAP function **shall** receive the Horizontal Position Integrity Containment Region (HPL$_{STP}$) from the own-ship navigation sources when available.

9.7. (Optional) The ASSAP function **shall** receive the Vertical Position Integrity Containment Region (VPL$_{STP}$) from the own-ship navigation sources when available.

10.8. The ASSAP function **shall** receive the Surveillance Integrity Level (SIL$_{STP}$) from the own-ship navigation sources when available.

2.2.2.4   [j4]ASSAP Input Requirements from CDTI

ASSAP input requirements from the CDTI are defined in Section 2.3.1.4 Outputs from CDTI to ASSAP. The ASSAP function **shall** be capable of receiving and processing the CDTI outputs to ASSAP as defined in Section 2.3.1.4 Outputs from CDTI to ASSAP.

2.2.2.5   ASSAP Output Requirements to CDTI

This section defines the traffic, alert, own-ship, and ASSAP status output requirements from the ASSAP function to the CDTI.

2.2.2.5.1   Traffic Information Output Requirements

The following subsections contain traffic information output requirements from the ASSAP function to the CDTI.

2.2.2.5.1.1   Traffic Output Capacity

The ASSAP function **shall** provide a traffic capacity of at least 60 tracks to the CDTI.

Note: A traffic capacity of 60 tracks is based on supporting 30 for surface traffic and 30 for airborne traffic.

2.2.2.5.1.2   Traffic Output Priority

The ASSAP function **shall** provide the highest priority tracks to the CDTI based on the following priority:

1. Resolution Advisory (for systems integrated with TCAS)

2. ASA Application Warning Alerts

3. Traffic Advisory (for systems integrated with TCAS)

4. ASA Application Caution Alerts

5. Proximate Traffic (for systems integrated with TCAS)

6. ASA Application Advisory Alerts

7. Coupled Traffic

8. Selected Traffic

9. Application Specific and/or Flight Crew Input Track Prioritization. The minimum requirement for application specific and/or flight crew input track prioritization is to include range and altitude prioritization for the tracks, whereby tracks that are closer in range and closer in altitude have a higher priority than those that are further away in range and further separated by altitude. Optionally, the prioritization may include additional factors to prioritize tracks for operational relevance to the active ownship ASA application(s).

Note: The application specific and/or flight crew input prioritization could be implemented in a variety of ways and a specific algorithm for performing this prioritization is not specified in this MOPS. As a minimum requirement, it is necessary to include both range and altitude prioritization. Optionally, other factors (in addition to range and altitude) may be used to prioritize tracks for operational relevance including, for example, closure rate, relative bearing (e.g., in front of or behind the ownship), airborne/ground state of ownship and/or traffic, track location relative to a runway, etc. It is not sufficient to simply have a closest range relevance prioritization, because, for example, during a cruise phase of flight, over-flying a busy airport could result in prioritizing ground targets that are relatively close to ownship higher than operationally relevant airborne threats. As another example, during the final stages of an approach, tracks on the intended landing runway should have higher priority than tracks on taxiways and in the gate area, but may not be closer in range to the ownship aircraft.

2.2.2.5.1.3 Track ID

The ASSAP function **shall** provide a Track ID for traffic sent to the CDTI.

When new traffic has been added due to traffic being dropped, the new traffic **shall** use a new Track ID identifier (not the same Track ID identifier that was used for the dropped traffic). Otherwise, the CDTI may mistake the new traffic as the dropped traffic. The only exception is when the new traffic was the same track that was previously dropped.

Note: The Track ID is a unique identifier that identifies the traffic for which data is being provided.

2.2.2.5.1.4 Flight ID

For the CD and EV App. applications, the ASSAP function **shall** provide a Flight ID for traffic sent to the CDTI when available.

Note: Flight ID is also desired (optional) for the EV Acq., ASSA, and FAROA applications.

2.2.2.5.1.5   Traffic Category (Emitter Category)

For the EV App. application, the ASSAP function **shal**l provide a Traffic Category for traffic sent to the CDTI when available.

Note: Traffic Category is also desired (optional) for the EV Acq., CD, ASSA, and FAROA applications.

2.2.2.5.1.6   Traffic Length/Width Codes (Desired/Optional)

The ASSAP function may provide Traffic Length/Width Codes for traffic sent to the CDTI when available.

2.2.2.5.1.7   Traffic Horizontal Position

The ASSAP function **shall** provide Traffic Horizontal Position for traffic sent to the CDTI.

Traffic Horizontal Position **shall** be provided as either ~~WGS 84~~ latitude/longitude or relative range and bearing referenced from own-ship position.

Traffic relative range and bearing from own-ship **shall** be calculated based on the Own-ship Horizontal Position source defined in Section 2.2.2.5.3.1 Own-ship Horizontal Position.

2.2.2.5.1.8   Traffic Horizontal Velocity

For the EV App. application, the ASSAP function **shall** provide Traffic Horizontal Velocity for traffic sent to the CDTI when available.

~~Traffic Horizontal Velocity **shall** be provided as either Cartesian coordinates of velocity (e.g., north and east velocity components) or as the magnitude of the traffic horizontal velocity (traffic ground speed).~~

Note:

1. Traffic Horizontal Velocity is used for displaying traffic velocity vectors or ground speed.

2. Traffic Horizontal Velocity is also desired (optional) for the EV Acq., CD, ASSA, and FAROA applications.

The CDTI MOPS needs to consider adding a requirement for displaying either Closure Rate or Ground Speed in order to satisfy the EV App. application.

2.2.2.5.1.9 Traffic Closure Rate

For the EV App. application, the ASSAP function **shall** provide Traffic Closure Rate for the coupled traffic sent to the CDTI when available.

Traffic Closure Rate **shall** be calculated based on the slant range from own-ship position.

Note: Traffic Closure Rate may also be used for the EV Acq., CD, ASSA, and FAROA applications.

2.2.2.5.1.10 Traffic Altitude

The ASSAP function **shall** provide Traffic Altitude for airborne traffic sent to the CDTI when available.

Traffic Altitude **shall** be provided as either actual pressure altitude or relative altitude to own-ship altitude.

Note:

1.   Traffic Altitude is not required for surface traffic.

2.   Traffic Altitude is used for displaying relative or actual altitudes for traffic. Own-ship pressure altitude is also needed for the CDTI to calculate traffic relative altitude when traffic actual pressure altitude is only provided or to calculate traffic actual altitude when traffic relative altitude is only provided.

2.2.2.5.1.11 Traffic Geometric Altitude (Optional)

The ASSAP function may provide Traffic Geometric Altitude for traffic sent to the CDTI when available.

Traffic Geometric Altitude **shall** be provided as ~~WGS-84~~ Height above Ellipsoid (HAE) geometric altitude.

Note:

1.   Traffic Geometric Altitude is not needed for surface traffic.

2.   Traffic Geometric Altitude may be used for displaying relative altitude when Pressure Altitude is unavailable.

2.2.2.5.1.12 Traffic Track Angle (Traffic Directionality)

The ASSAP function **shall** provide Traffic Track Angle for traffic sent to the CDTI when available.

Traffic Track Angle **shall** be provided as true track angle.

When true track angle is determined based on the Cartesian coordinates of velocity (e.g., north and east velocity components), t~~The Traffic Track Angle **shall** be considered invalid when the ~~Traffic Horizontal Velocity is below 20 kts~~traffic track angle error is greater than 30 degrees. See appendix I for information on traffic track angle errors.~~.~~

~~(Optional) If the traffic's reported NAC$_V$ or NUC$_R$ is greater than or equal to 3 (<1 m/s), then the Traffic Track Angle **shall** be considered invalid when the Traffic Horizontal Velocity is below 10 kts.~~

[j5]*Note:*

1. *Traffic Track Angle is used for calculating Traffic Directionality displayed on the CDTI.~~y.~~*

2. ~~*The Traffic Track Angle accuracy may be in question below the determined 20 and 10 kt thresholds.*~~

2.2.2.5.1.13   Traffic Vertical Direction

The ASSAP function **shall** provide a Traffic Vertical Direction for airborne traffic sent to the CDTI when available.

Traffic Vertical Direction **shall** be provided as either actual traffic vertical rate or as an indication whether the traffic vertical direction is climbing, descending, or level.

If the traffic vertical direction is calculated by ASSAP a climb shall be indicated when there is a positive vertical rate exceeding 500 fpm; a descent shall be indicated when there is a negative vertical rate exceeding 500 fpm.

Note:

1. *Traffic Vertical Direction is not required for surface traffic.*

2. ~~*Traffic Vertical Direction is used for displaying vertical direction for traffic (e.g., up or down arrow typically based on exceeding +/- 500 fpm).*~~

3. ~~*Based on the RTCA DO-302 STP MOPS, the received traffic vertical rate will be based on geometric vertical rate in most cases.*~~

2.2.2.5.1.14   Traffic **Air/**Ground Status

The ASSAP function **shall** provide a Traffic **Air/**Ground Status for traffic sent to the CDTI.

Note: ~~*Traffic*~~ *Traffic Air/Ground Status is used for differentiating between airborne and surface traffic on the display.*

2.2.2.5.1.15 Traffic TCAS Correlated Status

For systems integrated with TCAS, the ASSAP function **shall** provide a Traffic TCAS Correlated Status for traffic sent to the CDTI.

Note: *Traffic TCAS Correlated Status indicates that the traffic source (i.e., ADS-B, ADS-R, or TIS-B track) is correlated with an existing TCAS track or the traffic source is TCAS.*

2.2.2.5.1.16 Traffic Application Capability

The ASSAP function **shall** provide a Traffic Application Capability for traffic sent to the CDTI.

The Traffic Application Capability **shall** include that the traffic application capability is either Invalid or ~~Good Performance~~ Valid.

~~Note:~~

~~1.~~ The Traffic Application Capability should be provided for all available applications (not just the active applications). An indication that the traffic is of Degraded Performance is optional.

~~2.~~ For the EV Acq. application, the traffic application capability represents the following (EV Acq. is for airborne traffic and for surface traffic when not overlaid over an airport map):

   1. Invalid: Traffic not displayed; traffic does not meet the minimum performance criteria for display. This traffic may not be transmitted and may be replaced by an existing correlated TCAS track.

   2. Degraded Performance (Optional): Traffic degraded performance accuracy; traffic meets the degraded performance criteria for display.

   3. ~~Good Performance~~Valid: Traffic good performance accuracy; traffic meets the good performance criteria for display.

~~3.~~ For the CD application, the traffic application capability represents the following:

   1. Invalid: Traffic not qualified to alert; traffic does not meet the minimum performance criteria for alerting.

   2. Degraded Performance (Optional): N/A.

   3. ~~Good Performance~~Valid: Traffic qualified to alert.

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4. For the ASSA and FAROA applications, the traffic application capability represents the following (ASSA and FAROA are for surface traffic when overlaid over an airport map):

1. <u>Invalid</u>: Traffic not qualified for ASSA and FAROA.

2. <u>Degraded Performance (Optional)</u>: Traffic qualified for ASSA and FAROA, but with degraded performance.

3. ~~Good Performance~~<u>Valid</u>: Traffic qualified for ASSA and FAROA.

5. For the EV App. application, the traffic application capability represents the following:

1. <u>Invalid</u>: Traffic not qualified for EV App.

2. <u>Degraded Performance (Optional)</u>: Traffic qualified for EV App, but with degraded performance.

3. ~~Good Performance~~<u>Valid</u>: Traffic qualified for EV App.

2.2.2.5.1.17 Traffic Selected Status (Optional)

The ASSAP function may provide a Traffic Selected Status for traffic sent to the CDTI when available.

Note: *Traffic Selected Status may be used for systems that require feedback from the ASSAP function to the CDTI on which traffic is selected.*

2.2.2.5.1.18 Traffic Coupled Status (Optional)

The ASSAP function may provide a Traffic Coupled Status for traffic sent to the CDTI when available.

Note: *Traffic Coupled Status may be used for systems that require feedback from the ASSAP function to the CDTI on which traffic is coupled. This may be important for ASSAP implementations that only provide traffic data for the coupled traffic (e.g., Traffic Closure Rate for the EV App. application). This may not be important for ASSAP implementations that send Traffic Closure Rate for all traffic to the CDTI.*

2.2.2.5.1.19 Alert Output Requirements

The following subsections contain alert output requirements from the ASSAP function to the CDTI.

Note: *Currently the alerts are only associated with traffic for the CD application and for systems integrated with TCAS.*

~~2.2.2.5.1.20~~2.2.2.5.1.19.1 (Optional) Traffic ASA Application Alerts

For the CD application, the ASSAP function **shall** provide Traffic Collision Avoidance Zone (CAZ) and Conflict Detection Zone (CDZ) alerts (see DO-289) for traffic sent to the CDTI when available.

Note: CD Low level alerts are optional (see RTCA DO-289).~~.~~

~~2.2.2.5.1.21~~2.2.2.5.1.19.2 Traffic TCAS Alert Status

For systems integrated with TCAS, the ASSAP function **shall** provide a Traffic TCAS Alert Status for traffic sent to the CDTI when available.

Traffic sources (i.e., ADS-B, ADS-R, or TIS-B tracks) that are correlated with TCAS tracks and TCAS only tracks **shall** include the Traffic TCAS Alert Status (i.e., no threat, proximity traffic, traffic advisory, resolution advisory).

2.2.2.5.2 Own-ship Information Output Requirements

The following subsections contain own-ship information output requirements from the ASSAP function to the CDTI.

2.2.2.5.2.1 Own-ship Horizontal Position

The ASSAP function should ~~shall~~ provide the Own-ship Horizontal Position based on WGS-84 latitude/longitude to the CDTI.

If ASSAP provides own-ship horizontal position to the CDTI, the position provided **shall** meet the requirements defined in Table 2-2. [j6]

~~The Own-ship Horizontal Position data source **shall** be the same as the position source transmitted out by the ADS-B transmitter per RTCA DO-302 STP MOPS.~~

~~The CDTI **shall** use the Own-ship Horizontal Position provided by ASSAP since it represents the system's selected surveillance source.~~ ~~Note: CDTI implementations on MFDs must take careful considerations of data sources. For example the flight plan may be drawn based on different sources of own-ship horizontal position.~~[j7]

Note:

1. *For the ASSA and FAROA applications, own-ship horizontal position is needed for positioning own-ship relative to an airport surface map.*

2. *If Traffic Horizontal Position is provided as WGS-84 latitude/longitude, Own-ship Horizontal Position is needed for positioning traffic relative to own-ship.*

2.2.2.5.2.2   **Own-ship Horizontal Velocity**

For the EV App. application, the ASSAP function ~~shall~~ should provide the Own-ship Horizontal Velocity to the CDTI.

If ASSAP provides own-ship horizontal velocity to the CDTI, the velocity provided **shall** meet the requirements defined in Table 2-2. [j8]

~~The Own-ship Horizontal Velocity data source **shall** be the same as the velocity source transmitted out by the ADS-B transmitter per RTCA DO-302 STP MOPS.~~

~~The CDTI **shall** use the Own-ship Horizontal Velocity provided by ASSAP since it represents the system's selected surveillance source. Note: CDTI implementations on MFDs must take careful considerations of data sources. For example, MFDs may already be displaying own-ship ground speed based on different sources.~~

~~Own-ship Horizontal Velocity **shall** be provided as either Cartesian coordinates of velocity (e.g., north and east velocity components) or as the magnitude of the own-ship horizontal velocity (own-ship ground speed).~~

~~Note: Own-ship Horizontal Velocity is used for displaying own-ship velocity vectors or own-ship ground speed.~~

2.2.2.5.2.3   **Own-ship Track Angle**[j9]

The ASSAP function may provide Own-ship track angle to the CDTI.

If ASSAP provides own-ship track angle to the CDTI, the track angle provided **shall** meet the following requirements:

~~The ASSAP function **shall** provide the Own-ship Track Angle to the CDTI.~~

Own-ship Track Angle **shall** be provided as true track angle.

When own-ship track angle is to be used to orient the display, Own-ship Track Angle **shall** be considered invalid when the own-ship track angle error is greater than 5 degrees. See appendix I for information on track angle errors.

When own-ship track angle is to be used to orient the own-ship symbol, the Own-ship Track Angle **shall** be considered invalid when the own-ship track angle error is greater than 30 degrees. See appendix I for information on track angle errors.

When true track angle is determined based on the Cartesian coordinates of velocity (e.g., north and east velocity components), the Own-ship Track Angle **shall** be considered invalid when the Own-ship Horizontal Velocity is below 20 kts.

(Optional) If the own-ship's reported HFOM$_{RSTP}$ is less than or equal to 1 m/s, then the Own-ship Track Angle **shall** be considered invalid when the Own-ship Horizontal Velocity is below 10 kts.

[j10]*Note:*

1.   Own-ship Track Angle is used for calculating Traffic Directionality.

2.   The Own-ship Track Angle accuracy may be in question below the determined 20 and 10 kt thresholds.

2.2.2.5.2.4   Own-ship Pressure Altitude

The ASSAP function **shall** provide the Own-ship Pressure Altitude to the CDTI.

Note: Own-ship Pressure Altitude is needed for the CDTI to calculate traffic relative altitude when traffic actual pressure altitude is only provided or to calculate traffic actual altitude when traffic relative altitude is only provided.

2.2.2.5.2.5   Own-ship Length/Width Codes (Optional)

For the ASSA and FAROA applications, the ASSAP function may provide the Own-ship Length/Width Codes to the CDTI.

2.2.2.5.3   ASSAP Status Output Requirements

The following subsections contain ASSAP status output requirements from the ASSAP function to the CDTI.

2.2.2.5.3.1   ASA Application Status

The ASSAP function **shall** provide the ASA Application Status to the CDTI. This status is based upon own-ship's data meeting individual application requirements.

The ASA Application Status **shall** include that the ASA Application is one of the following five states: On, Available to Run, Unavailable to Run, Unavailable – Fault, or Not Configured.

Note: The ASSAP function should provide the ASA Application Status for the EV Acq., CD, ASSA, FAROA, and EV App. applications. The ASA Application Status represents the following:

1. On: Application is on/running; required own-ship input data is available and meets the performance criteria.

2. Available to Run: Application is configured. Required input data is available and meets the performance criteria (This state represents that the ASA Application is manually or automatically selected off).[j11]

3. Unavailable to Run: Required Input data is available but does not meet the performance criteria or is not available due to NCD conditions.

4. Unavailable - Fault: Required Input data is not available due to a failure or the ASA Application process is failed.

5. Not Configured: Application is not installed.

2.2.2.5.3.2   ASSAP Fault

An ASSAP Fault **shall** be provided to the CDTI when the required input dataper the fault requirements in Section 2.2.4.3 Monitoring. is not available due to a failure or the ASSAP process function is failed. For detailed fault requirements, reference Section 2.2.4.3 Monitoring.

2.2.3   Surveillance Processing

Surveillance processing includes the functions source-level track generation and maintenance, inter-source correlation, and best source selection. The purpose of source-level track generation and maintenance is to establish tracks from ADS-B/ADS-R and TIS-B sources separately and thereafter maintain the tracks. Note that TCAS effectively provides source-level tracking for ATCRBS or Mode S equipped aircraft within range of the TCAS sensor. The purpose of inter-source correlation is to perform correlation between source-level tracks (ADS-B/ADS-R tracks and TIS-B and TCAS tracks) to detect when an A/V is tracked by multiple sources; to perform correlation between Ownship track and TIS-B track to remove "shadows" on Ownship; and to perform correlation between TCAS reports and current source-level tracks and tag the source-level tracks with the correlation status. The purpose of best source selection is to select the best track when source-level tracks from ADS-B/ADS-R and TIS-B sources correlate.

A functional architecture for surveillance processing is illustrated in

Figure 2-4 Example Surveillance Processing Architecture

Surveillance Processing

Ownship Information

[1]ADS-B/ADS-R/ TIS-B Reports

Track Generation & Maintenance

Initiated/ Updated Tracks

Inter-Source Correlation

Uncorrelated TCAS Tracks

[2]Correlation Tags

TCAS Tracks

Active Tracks

Active Tracks

Track File Database

Correlation Tags

Best Source Selection

Best/Worst Tracks

Application Processing

Track Termination After Coast Interval

Active Tracks

Terminated Tracks

Best Active Tracks

Common Time Track Extrapolation

≥ 1 Hz

Traffic State File

~~Figure 2-4 Example Surveillance Processing Architecture~~Figure 2-4 Example ~~Surveillance Processing Architecture~~, which shows the relationships among these functions, as well as their relationships to the upstream function, surveillance (not part of ASSAP) and the downstream function, application processing.
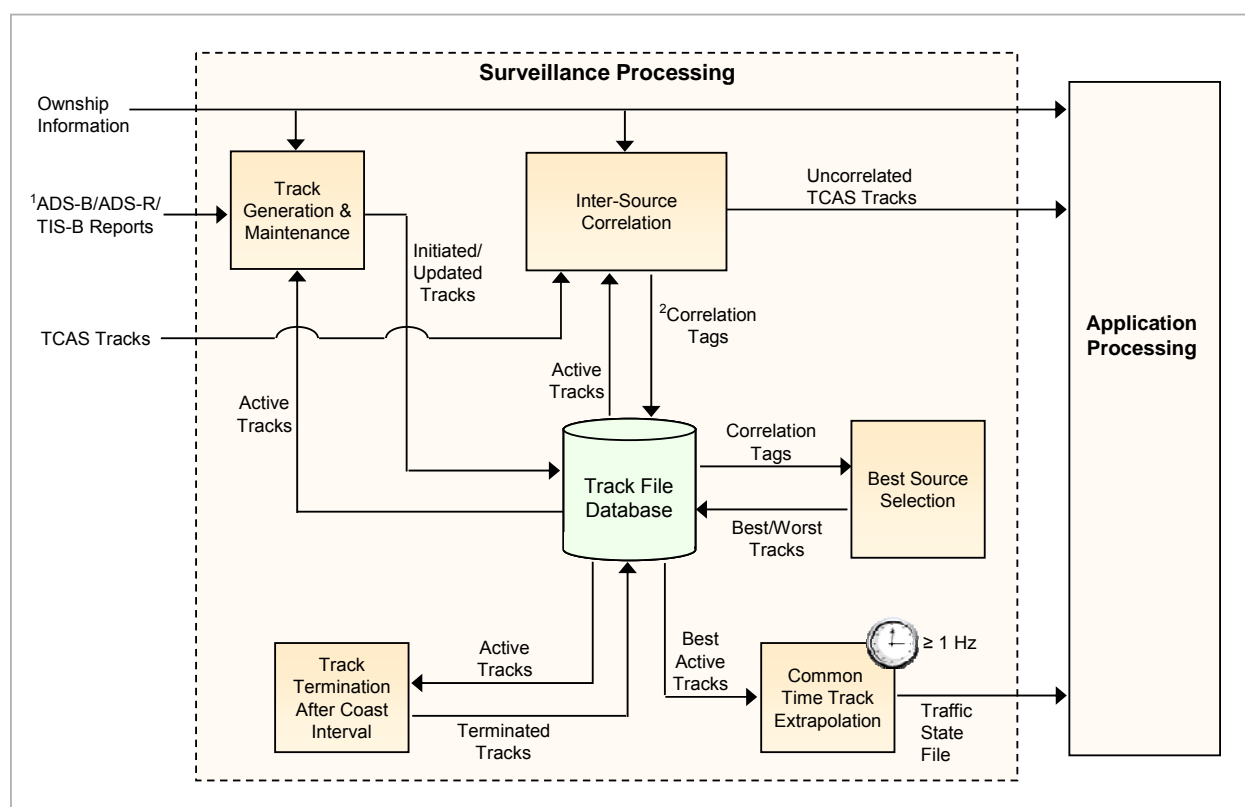
Figure 2-4 Example Surveillance Processing Architecture

The rationale for this architecture is the need to provide tracks from the best source (if more than one) to application processing, while avoiding the complexity of a fusion tracker as a minimum requirement. However, these requirements do not preclude the use of sensor fusion techniques. The rarity of simultaneous reporting of an A/V by both TIS-B and ADS-B services does not necessitate requiring the complexity of "fusion" tracking. It is desireable, in Tthe rare case in which both services report on the same A/V must that this be detected by ASSAP to mitigate sending dual tracks to the CDTI for the same A/V.

2.2.3.1 Source Level Track Generation

Reports from each available source (i.e., ADS-B, ADS-R, and TIS-B) are tracked and maintained separately.

a. ASSAP **shall** attempt to correlate each received report to an existing track; report to track correlation logic should take into consideration address, altitude, velocity, position, and quality.

b. A track **shall** be updated when a report correlates with the track.

c. ~~A report **shall** initiate a new track when the report does not correlate with an existing track.~~[j12]

d. ~~Report to track correlation logic **shall** take into consideration all of the following criteria: address, altitude, velocity, position, and quality.~~

~~e.~~c. The correlation algorithm **shall** perform at least as well as the example algorithm given in Appendix C~~TBD~~ with respect to distinguishing unique tracks ~~and~~ miscorrelating reports, and initiating new tracks. This intent is met by passing the correlation test scenarios given in section 2. ~~TBD~~.

——If ASSAP supports CD, ASSAP **shall** be capable of maintaining at least 130 source tracks. Priority will determine which tracks are maintained when more than 130 unique reports are presented to ASSAP. If ASSAP does not support CD, ASSAP shall be capable of maintaining at least 60 source tracks; in this case priority will determine which tracks are maintained when more than 60 unique reports are presented to ASSAP. Track prioritization is described in section XX. These requirements do not include TCAS tracks.

d. ~~Note: Source tracks do not include TCAS tracks (**Requirement needed**).~~

e. ASSAP track correlation shall distinguish source reports with duplicate addresses at least as well as the example algorithm given in Appendix C.

Note: ASSAP track correlation assumes that 1090 MHz ADS-B duplicate addresses will result in a single set of reports presented at the input to ASSAP. These reports could have corrupted velocity, ID, and quality and ASSAP will not attempt to detect or repair this case.

2.2.3.1.1 Track Estimation

a. Track estimates **shall** be generated at a rate of 1 Hz or greater.

b. Track estimates **shall** include target horizontal position, barometric altitude, and geometric altitude (when barometric altitude is not available), estimated to a common time of applicability (within +/- 200 mS) for all tracks.

2.2.3.2 Inter-source Correlation

The purpose of inter-source correlation is to ensure that a single target detected on different surveillance sources is properly identified as such to prevent the display of spurious targets on the CDTI. See Appendix C ~~TBD~~ for one acceptable method of performing inter-source correlation.[j13]

2.2.3.2.1 Correlation of ADS-B, ADS-R, and TIS-B Tracks

The inter-source correlation algorithm ~~shall~~ should perform at least as well as the example algorithm given in Appendix ~~TBD~~ C with respect to distinguishing unique tracks and miscorrelating tracks between ADS-B, ADS-R, and TIS-B sources. This intent is met by passing the correlation test scenarios given in section 2.6.5 ~~TBD~~.

2.2.3.2.2 Correlation of TIS-B with Ownship

The inter-source correlation algorithm **shall** perform at least as well as the example algorithm given in Appendix C~~TBD~~ with respect to correlating a TIS-B shadow with Ownship. This intent is met by passing the correlation test scenarios given in section 2.6.5 ~~TBD~~.

2.2.3.2.3 Correlation of TCAS with ADS-B, ADS-R, and TIS-B Tracks

The inter-source correlation algorithm *shall* perform at least as well as the example algorithm given in Appendix C~~TBD~~ with respect to distinguishing unique tracks and miscorrelating tracks between TCAS and ADS-B, ADS-R, or TIS-B sources. This intent is met by passing the correlation test scenarios given in section 2.6.5 ~~TBD~~.

2.2.3.3 Best Source Selection

When multiple source tracks correlate, the best quality source track **shall** be chosen using the following criteria in priority order:

1. Source with the greatest reported SIL (with a non-zero NIC)

2. Source with the greatest reported NIC

3. Source with the greatest NACp

4. Source with the greatest NACv

TCAS reports do not contain any of these criteria. When a TCAS track correlates with an existing track it **shall** only be chosen as the best track when all other source position accuracies drop below the minimum threshold for performing the Enhanced Visual Acquisition application. This establishes a minimum requirement for source selection and is not intended to prohibit source fusion techniques.

When the selected source has not been updated and the maximum data age is exceeded, the next highest quality source may~~shall~~ be selected. The maximum data age is different from application to application (see Table 2-1~~TBD~~). When running multiple applications, the maximum data age of the most stringent application running may~~shall~~ be used.

It is recognized that alternate means of dealing with data age exist. For instance, the accuracy parameters may be extrapolated over time and used to determine when to select

an alternate source. These requirements are not intended to prevent more sophisticated designs.

If the update rate of a data source is less frequent than the maximum allowed data age for an application, a manufacturer may choose to exclude that data source from selection for that application. That may prevent periodic interruption of the application.

2.2.3.4 Track Termination

ASSAP **shall** terminate a track when the maximum ~~coast interval~~data age has been exceeded for all of the applications for which the track is potentially being used. The ~~coast interval~~data age is the elapsed time since a report from any source has been correlated with the track.

2.2.4 Application Processing

The application processing section contains specific requirements for EV Acq., CD, ASSA, FAROA, and EV App. Each application determines the traffic application capability for each target. Ownship and traffic quality/integrity data is used to determine the traffic application capability. Application processing also includes the processing of alerts (e.g., CD alerts) and ~~guidance~~ other information (e.g., Traffic closure rate for EV App). An example application processing architecture is shown in Figure 2-5. The track state file is provided by surveillance processing.
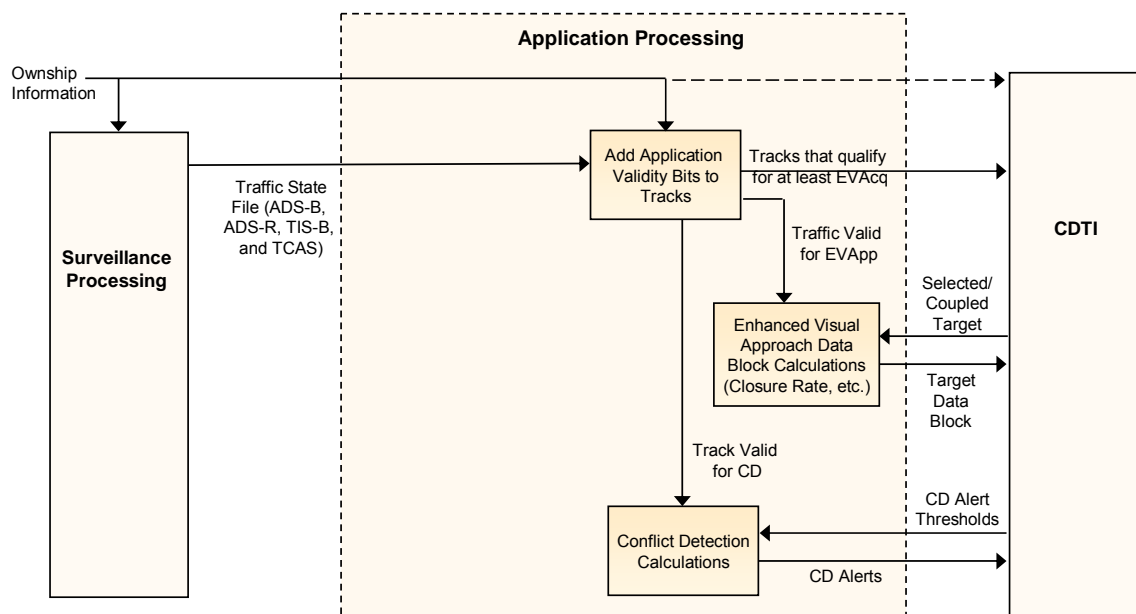
1) Uncorrelated TCAS tracks (i.e. TCAS is the only surveillance source for a target) and correlated/best-source TCAS tracks (i.e. TCAS is the best surveillance source for a target) are merged into the traffic state file; TCAS tracks are not extrapolated, resulting in a maximum 1 second data age from the time of transfer to ASSAP (the traffic state file is recalculated at 1 Hz).
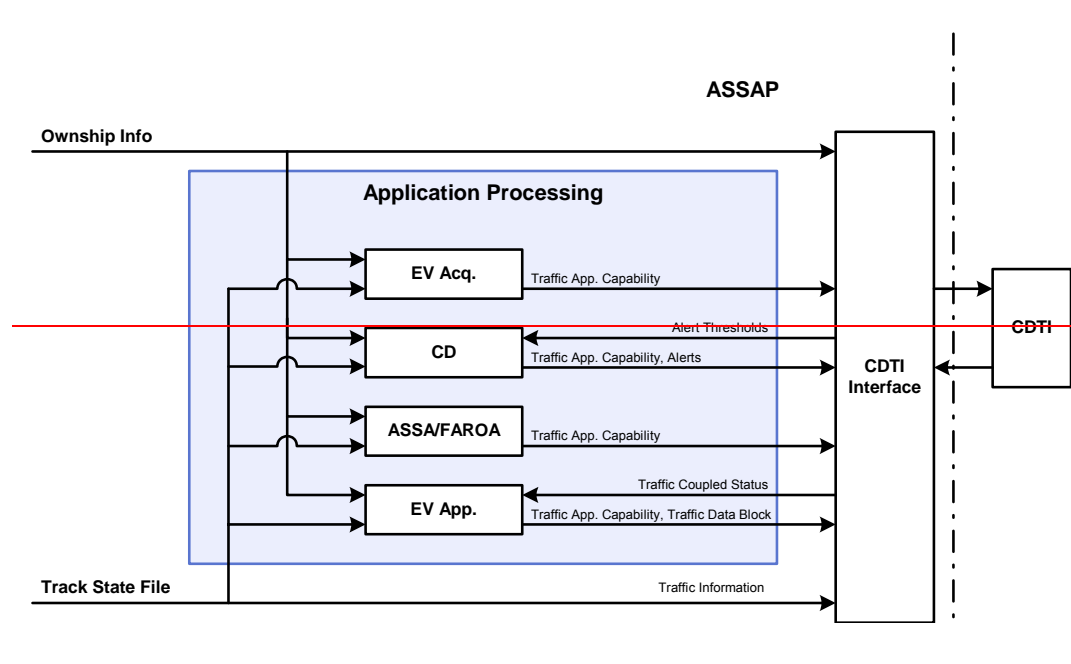
Figure 2-5 Example Application Processing Architecture[j14]

Table 2-1 summarizes the Target Vehicle requirements for each application. Table 2-2 summarizes the Ownship requirements for each application. The individual requirements are covered in detail in the following subparagraphs.

Table 2-1 Target Vehicle Application Specific Requirements Summary

Requirement Category	Requirement	Applicable Subsystem Interfaces (See Figure TBD)	EVAcq	CD	ASSA FAROA	EVApp
State Data	Horizontal Position Accuracy	A1→B1	0.5 NM	0.5 NM	92.6 m	0.3~~1~~ NM
	Degraded Position Accuracy	A1→B1	N/A	N/A	~~(NA~~185.2 m) optional	~~0.3 NM~~N/A
	Horizontal Velocity Accuracy	A1→B1	N/A	~~3 m/s~~ ~~0.6 m/s~~ ~~desired~~manufacturer determined parameter	~~N/A~~?? 3 m/s ??	10 m/s
	Heading Accuracy	~~A1→B1~~ ~~NA~~ ~~NA~~ ~~?? 10 deg ??~~ ~~NA~~this row to be deleted				
	Vertical Position Accuracy	A1→B1	Baro or VEPU < 45 m	Baro or VEPU < 45 m	Baro or VEPU < 45 m (when airborne)	Baro or VEPU < 45 m
	Vertical Velocity Accuracy	A1→B1	N/A	Valid Baro	Valid Baro (when airborne)?? 15 fps ??	Valid Baro~~NA~~
State Data Integrity	Integrity Containment Risk	A1→B1	~~N/A~~10e-2/hr	~~N/A~~10e-2/hr	~~N/A~~10e-3/hr	10e-3/hr
	Integrity Containment Bound	A1→B1	N/A	~~N/A~~1 NM	~~N/A~~0.1 NM	0.~~2~~5 NM
State Data Timing	Maximum Latency	A1→G	6 s	6 s	6 s	6 s
		A1→B1	1 s (0.6 s)	1 s (0.6 s)	1 s (0.6 s)	1 s (0.6 s)
		B1→D	1.1 s	1.1 s	1.1 s	1.1 s
		D→E	0.5 s	0.5 s	0.5 s	0.5 s
		E→F	2 s	2 s	2 s	2 s
		F→G	0.5 s	0.5 s	0.5 s	0.5 s

	~~Maximum Data Age until Degraded ADS-B (TIS-B)~~ ~~at E~~ ~~NA~~ ~~6 s~~ ~~NA~~This row to be deleted ~~10 s~~				
	Maximum Data Age until Dropped ADS-B ~~(TIS-B)~~	at E	~~TBD~~25 s ~~(25 s)~~	25~~30~~ s	11 s~~TBD (11 s)~~ moving 25~~15~~ s ~~(15 s)~~ static -- recommened	15 s
ID/Status Information	Maximum Latency	A1→G	30 s	30 s	30 s	30 s

Table 2-2 Ownship Application Specific Requirements Summary[j15]

Requirement Category	Requirement	Applicable Subsystem Interfaces (See Figure TBD)	EVAcq	CD	ASSA FAROA	EVApp
State Data Accuracy	Max Horizontal Position Accuracy	A3→B3	0.5 NM	0.5 NM 20 m desired	74 m	0.1 NM
	Max Degraded Horizontal Position Accuracy	A3→B3	NA	NA	NA	0.3 NM
	Maximum Horizontal Velocity Error	A3→B3	NA	?? 3 m/s ?? 0.3 m/s desired	NA	10 m/s
	Heading Accuracy	A3→B3	NA	NA	NA	NA
	Vertical Position Accuracy	A3→B3	Baro or VEPU < 45m	Baro or VEPU < 45m	Baro or VEPU < 45	Baro or VEPU < 45m
	Vertical Velocity Accuracy	A3→B3	NA	Baro	NA	NA
State Data Integrity	Integrity Containment Risk	A3→B3	10e-2/hr	?? 10e-2/hr ??	10e-3/hr	10e-3/hr
	Horizontal Integrity Containment Radius, Rc	A3→B3	NA	1 NM	0.1 NM	0.2 NM
	Vertical Integrity Containment Bound	A3→B3	NA	NA	NA	NA
State Data Timing	Maximum Latency	A3→F	600 ms	600 ms	600 ms	600 ms

2.2.4.1 ~~General Requirements~~Reserved

~~A precision installation is one where the ownship position data is known within 100 ms of the actual UTC time. Typically a precision installation includes the GPS Time Mark and data bus wired directly to the ASSAP processor. It is possible to meet the timing requirement without the Time Mark, but the system timing must be shown to be deterministic within the tolerance. In precision installations, ownship position data **shall** be delivered to ASSAP such that the uncompensated latency is less than 200 ms. A GPS sensor compliant with ARINC 743A-4 is an example of an acceptable position source.~~

~~In a non-precision installation, ownship position data **shall** be delivered to ASSAP such that the uncompensated latency is less than 600 ms. A RNP FMS compliant with ARINC 702A Supplement 3 is an example of an acceptable position source.~~

2.2.4.2 [j16]Application-Specific Requirements

2.2.4.2.1 Enhanced Visual Acquisition (EVAcq)

ASSAP's contribution to this application includes the tracking and target correlation requirements that are applicable to all applications. ASSAP also determines whether ownship information and target vehicle information is good enough to perform EVAcq. ~~The delivery of target information to the CDTI interface is the final step of ASSAP's EVACq responsibility.~~

2.2.4.2.1.1 Ownship Requirements for EVAcq

ASSAP may perform the Enhanced Visual Acquisition application when Ownship horizontal position is valid. When Ownship horizontal position is invalid, ASSAP **shall** (R2.xxx) signal that EVAcq is inoperative via the CDTI interface. When Ownship horizontal position accuracy is ~~greater~~ worse than 0.5 Nm (1852m), ASSAP **shall** (R2.xxx) signal that EVAcq is inoperative via the CDTI interface.

ASSAP may perform the Enhanced Visual Acquisition application when Ownship pressure altitude is invalid. However, without Ownship altitude, the relative altitude tags on the targets will have to be removed from the display. This is considered a degraded mode. No ASSAP system should be designed or installed without a pressure altitude source.

2.2.4.2.1.2 Target Vehicle Requirements for EVAcq

All versions of existing ADS-B links are ~~eligible to~~capable of producing ~~be~~ EVAcq targets (e.g., DO-260 Version 0).

An EVAcq target **shall** (R2.xxx) be derived from a target track with valid horizontal position. A target track with NACp less than 5 or NUC less than 4 **shall** (R2.xxx) be dropped from the CDTI interface.

An EVAcq target may not be reporting barometric altitude. This condition is known as a non-altitude reporting target or NAR. If an EVAcq target is reporting Height Above the Ellipsoid (HAE), it may be used to compute a relative altitude, but only if the NACp is 9 or greater or NUC is 8 or greater AND ownship HAE Accuracy is less than 45 m.

If an EVAcq track's position is not updated within 25 seconds, ASSAP **shall** (R2.xxx) drop the target from the CDTI interface. This is a maximum allowed coast interval based on an enroute SSR TIS-B update. Manufacturers are encouraged to use shorter coast intervals for ADS-B and ADS-R targets. <May want to strengthen this requirement based on Larry Bachman's presentation>

Note: The initial application safety assessment determined the integrity requirement of this application to be 10^{-2}. This is the same order of magnitude as the accuracy parameter. As a result, the community SC-186 has decided that the accuracy parameter was sufficient to determine validity for this application.

2.2.4.2.2 Airport Surface Situational Awareness/Final Approach and Runway Occupancy Awareness (ASSA/FAROA)

ASSAP's contribution to this application includes the tracking and target correlation requirements that are applicable to all applications. ASSAP also determines whether Ownship information and target vehicle information is good enough to perform ASSA/FAROA. The delivery of target information to the CDTI interface is the final step of ASSAP's ASSA/FAROA responsibility.

2.2.4.2.2.1 Ownship Requirements for ASSA/FAROA

ASSAP may perform the ASSA/FAROA application when Ownship horizontal position and vertical position is valid and of sufficient quality. Vertical position is satisfied by Height Above the Ellipsoid (HAE), when VEPU < 45 m, or pressure altitude when airborne. Vertical position may also be satisfied when reporting "on the ground" status. When Ownship horizontal or vertical position is invalid, ASSAP **shall** (R2.xxx) signal that ASSA/FAROA is inoperative via the CDTI interface. When Ownship SIL is zero or the Radius of Containment is greater than 0.1 Nm (185.2 m) or accuracy is greater than 0.04 Nm (74 m), ASSAP **shall** (R2.xxx) signal that ASSA/FAROA is inoperative via the CDTI [j17]interface.

2.2.4.2.2.2 Target Vehicle Requirements for ASSA/FAROA

All versions of existing ADS-B links are eligible to becapable of producing ASSA/FAROA targets (e.g., DO-260 Version 0).

An ASSA/FAROA target **shall** (R2.xxx) be derived from a target track with valid horizontal and vertical position. Vertical position is satisfied by pressure altitude when airborne. If the target is reporting Height Above the Ellipsoid (HAE), it must be reporting

a NACp of 9 or greater or a NUC of 8 or greater to satisfy the vertical position requirement when airborne. This is because lower accuracy values do not bound VEPU. Vertical position is satisfied when reporting on the ground regardless of the validity of pressure altitude or HAE.

A DO-260A or DO-282A Version 1 surface target track **shall** (R2.xxx) have a NACp of 8 or greater (92.6m), a NIC of 8 or greater (0.1 NM), and a SIL of 1 or greater to be marked a valid ASSA/FAROA target on the CDTI interface.

A DO-260 or DO-282 Version 0 surface target track **shall** (R2.xxx) have a NUC of 7 or greater to be marked a valid ASSA/FAROA target on the CDTI interface.

Note: The ASSA/FAROA requirements for airborne targets are consistent with the EVAcq requirements. The only difference between EVAcq and ASSA/FAROA is that ASSA/FAROA requires ADS-B reports have a valid altitude to be displayed; surface targets do not.   . Without that, the presentation could depict an aircraft flying over the airfield at altitude. This is a nuisance at best, and potentially false and misleading information.

A DO-260A or DO-282A Version 1 airborne target track **shall** (R2.xxx) have a NACp of 5 or greater (0.5 NM) to be marked a valid ASSA/FAROA target on the CDTI interface.

A DO-260 version 0or DO-282 Version 0 airborne target track **shall** (R2.xxx) have a NUC of 4 (0.5 NM) or greater to be marked a valid ASSA/FAROA target on the CDTI interface[j18].

In motion is defined as moving more than 10 meters in 30 seconds. If an ASSA/FAROA target is in motion, the target position must be updated within 11 seconds, or ASSAP **shall** (R2.xxx) mark the target invalid for ASSA/FAROA on the CDTI interface. This coasting interval is based on the TIS-B update rate. Eleven seconds is twice the terminal radar sweep rate. A manufacturer is encouraged to use shorter coasting intervals for ADS-B and ADS-R targets. <May need to strengthen this based on Larry Bachman's presentation>

If an ASSA/FAROA target is not in motion, the target position must be updated within 15 seconds, or ASSAP **shall** (R2.xxx) mark the target invalid for ASSA/FAROA on the CDTI interface. Fifteen seconds is 3 times the low squitter rate and approximately 3 times the terminal radar sweep rate.

2.2.4.2.3   Conflict Detection (CD)

The objective of Conflict Detection (CD) is to enhance the flight crew's awareness of participating proximate traffic by providing alerts when aircraft separation is predicted to become compromisedto aid in "see and avoid" procedures.. The alerts may prompt the flight crew to exercise "see and avoid" proceduresadditional visual vigilance.. Avoidance maneuvers are not provided by the application, and the flight crew must not maneuver

based solely on the CDTI information. The CD application is a subset of the Airborne Conflict Management (ACM) application.

ASSAP's contribution to this application includes ~~the tracking and target correlation requirements that are applicable to all applications~~generating the alert, as well as determining~~. ASSAP determines~~ whether the quality of Ownship information and target vehicle information is sufficient to perform CD.

If the installed system has the option for conflict detection (CD), ASSAP **shall** (R3.199) determine if each track is eligible for CD processing, and accept alert threshold parameters from the CDTI Interface. Using the most recent set of these parameters, each track that is eligible for CD **shall** (R3.200) be processed by the CD alerting function, and the resulting CAZ alerts and CDZ alerts **shall** (R3.201) be issued as appropriate. Upon receiving a new set of alert threshold parameters, alerts determined from the previous set of parameters shall (R3.201b) be deleted, and a new set of alerts using the updated threshold parameters shall be issued. ASSAP **shall** (R3.202) include in the ASSAP track report the status of the CAZ alert and the CDZ alert.

~~The CD algorithm~~ **shall** ~~perform at least as well as~~ **[measured how? what metric?]** ~~the example algorithm given in Appendix TBD with respect to time to alert and false alarm rate.~~There are no minimum requirements on the CD algorithm. An example algorithm is provided in Appendix XX. ~~This intent is met by passing the conflict detection test scenarios given in section 2.TBD.~~

[do we say that CD should loop thru all tracks each second?]

2.2.4.2.3.1   Ownship Requirements for CD

ASSAP may perform the Conflict Detection application when Ownship horizontal and vertical positions are valid and of sufficient quality. Vertical position is satisfied by Height Above the Ellipsoid (HAE) or pressure altitude. When Ownship horizontal or vertical position is invalid, ASSAP **shall** (R2.xxx) signal that CD is inoperative via the CDTI interface. When Ownship horizontal position uncertainty is greater than 0.5 NM, ASSAP **shall** (R2.xxx) signal that CD is inoperative via the CDTI interface. When HAE is used for vertical position and Ownship vertical position uncertainty is greater than 45 m, ASSAP **shall** (R2.xxx) signal that CD is inoperative via the CDTI interface.

ASSAP may perform the CD application when Ownship horizontal velocity is of sufficient quality. When Ownship horizontal velocity uncertainty is greater than ~~3 m/s~~a manufacturer determined parameter value, ASSAP **shall** (R2.xxx) signal that CD is inoperative via the CDTI interface.

~~When Ownship Integrity Containment Risk is greater than 10^{-2}/hr or Radius of Containment is greater than 1 NM, ASSAP~~ **shall** ~~(R2.xxx) signal that CD is inoperative via the CDTI interface.~~

2.2.4.2.3.2 Target Vehicle Requirements for CD

~~TBD versions of existing ADS-B links are eligible to be CD targets (e.g., DO-260 Version 0).~~

A CD target **shall** (R2.xxx) be derived from a target track with valid horizontal and vertical position. Vertical position is satisfied by Height Above the Ellipsoid (HAE) or pressure altitude. When pressure altitude is used for vertical position, a target track **shall** (R2.xxx) have a NACp of 5 or greater to be marked as a valid CD target. When HAE is used for vertical position, a target track **shall** (R2.xxx) have a NACp of 9 or greater to be marked as a valid CD target.

A target track **shall** (R2.xxx) have a NACv of ~~2~~ a manufacturer determined minimum value or greater to be marked as a valid CD target.

~~A target track **shall** (R2.xxx) have a SIL of 0 (10^{-2}/hr) or greater and a NIC of 5 or greater to be marked as a valid CD target.~~

If a CD target track is not updated within 30 seconds, ASSAP **shall** (R2.xxx) mark the target as invalid for the Conflict Detection application.

2.2.4.2.4 [j19]Enhanced Visual Approach (EVApp)

The Enhanced Visual Approach (EVApp) application is an extension of the current visual approach procedure. In this application, the CDTI is used by the flight crew to detect and track the preceding aircraft more effectively, thereby ~~preventing numerous~~reducing the number of traffic call outs by ATC, allowing for the closure of large gaps between traffic, and reducing the number of go-arounds.

ASSAP's contribution to this application includes the tracking and target correlation requirements that are applicable to all applications. ASSAP also determines whether the quality of Ownship information satisfies the EVapp requirements, and notifies the CDTI if EVApp is available. If so, the pilot may select a target aircraft on the CDTI for EVApp.

Upon the selection of a target for EVapp, ASSAP **shall** (Rx.xx) receive the target identifier from the CDTI interface. ASSAP then determines if the quality of target vehicle information is sufficient to perform EVApp. If the target quality is insufficient, ASSAP **shall** (Rx.xx) notify the CDTI that EVApp is not available for this target. If the target quality is sufficient, ASSAP **shall** (Rx.xx) calculate the range and closure rate between Ownship and the selected target, and deliver that information to the CDTI interface. The method used to compute these values **shall** (Rx.xx) be at least as accurate as the Position and Velocity-Based Algorithm given in Section A.2.2.1.2 (note that NACv of at least 1 is required for the selected target, supporting the application of an algorithm using velocity as well as position).

The range and closure rate information, combined with the track state information also provided by ASSAP to the CDTI for all vehicles, is used to construct the EVApp

Datablock on the CDTI. This datablock contains the target vehicle ID (call sign/flight ID), ground speed, and range and closure rate with the Ownship.

On-board target vehicle velocity validation: requirement that says how to do it without a transmitted NACv, based hopefully on the ITP work.

2.2.4.2.4.1.1   Own Aircraft Requirements

ASSAP may perform the Enhanced Visual Approach application when own aircraft horizontal and vertical positions are valid and of sufficient quality. Vertical position is satisfied by Height Above the Ellipsoid (HAE) or pressure altitude. When own aircraft horizontal or vertical position is invalid, ASSAP SHALL (R2.xxx) signal that EVApp is inoperative via the CDTI interface. When own aircraft horizontal position uncertainty is greater than 0.1 NM (185.2 m), ASSAP SHALL (R2.xxx) signal that EVApp is inoperative via the CDTI interface. When HAE is used for vertical position and own aircraft vertical position uncertainty is greater than 45 m, ASSAP SHALL (R2.xxx) signal that EVApp is inoperative via the CDTI interface.

ASSAP may perform the Enhanced Visual Approach application when own aircraft horizontal velocity is of sufficient quality. When own aircraft horizontal velocity uncertainty is greater than 10 m/s, ASSAP SHALL (R2.xxx) signal that EVApp is inoperative via the CDTI interface.

When own aircraft Integrity Containment Risk is greater than 10^{-3}/hr or Radius of Containment is greater than 0.2 NM (370.4 m), ASSAP SHALL (R2.xxx) signal that EVApp is inoperative via the CDTI interface.

2.2.4.2.4.1.2   Target Vehicle Requirements

An EVApp target SHALL (R2.xxx) be derived from a target track with valid horizontal and vertical position. Vertical position is satisfied by Height Above the Ellipsoid (HAE) or pressure altitude. When pressure altitude is used for vertical position, a target track SHALL (R2.xxx) have a NACp of 7 or greater to be marked as a valid EVApp target. When HAE is used for vertical position, a target track SHALL (R2.xxx) have a NACp of 9 or greater to be marked as a valid EVApp target.

A target track SHALL (R2.xxx) have a NACv of 1 or greater to be marked as a valid EVApp target.

A target track SHALL (R2.xxx) have a SIL of 1 or greater and a NIC of 7 or greater to be marked as a valid EVApp target.

If an EVApp target is not updated within 15 seconds, ASSAP SHALL (R2.xxx) mark the target as invalid for the Enhanced Visual Approach application.

2.2.4.3   **Monitor Functioning**

Action Dean: generate a small description of the monitor function.

2.2.4.3.1   **General Requirements**

2.2.4.3.1.1   **Self Test**

The Monitor **shall** include a self-test function, capable of being initiated by the pilot. As a minimum, self-test **shall** test all audible and visual annunciators and activate each display element in a pre-determined temporal pattern to allow visual verification that display outputs issued by the digital processor can be correctly interpreted by the pilot. The self-test function **shall** not interfere with the normal operation of the equipment.

Note: Flight-crew-initiated operation of display indications for test purposes is not considered interference with normal equipment operation.

2.2.4.3.1.2   **Non Interference**

The Monitor **shall** not interfere with the normal operation of ASSAPA. Any RF test signals (RF signals?) used by the Monitor **shall** be restricted by the compatibility requirements [TCAS and ADS-B MOPS?]

2.2.4.3.2   **Monitoring of ASSAPAS Computer Resources**

ASSAPAS **shall** include provision for monitoring its computer resources. As a minimum this monitoring **shall** include random access memory (RAM) pattern tests, central processing unit (CPU) instruction tests, program memory tests, CPU input/output functions tests, and CPU timing tests. The Monitor shall be capable of detecting a failure in the computer performance monitoring and upon detection shall annunciate a failure. A means of computer performance testing is required to enable ASSAPS computer performance to be monitored both under normal bench test conditions and under environmental extremes. These computer performance tests may be included in the Monitor or may be a separate test program for use during environmental testing.

2.2.4.3.3   **ASSAPAS Input Data Monitoring**

2.2.4.3.3.1   **ADS-B Receive Subsystem**

ASSAPS **shall** monitor the ADS-B report interface from each ADS-B receiver. ASSAPS **shall** annunciate a failure on loss of input data from any ADS-B receive subsystem.

Note: *This could be accomplished though a periodic heartbeat message that would indicate function in the absence of traffic*

2.2.4.3.3.2 TCAS

AS~~S~~APS **shall** monitor TCAS output to verify TCAS function. ~~ASAS~~ ASSAP **shall** annunciate a failure on loss of data from TCAS

Note: *This could be accomplished though a periodic heartbeat message that would indicate function in the absence of traffic*

2.2.4.3.3.3 Ownship State Data

AS~~S~~APS **shall** monitor the inputs that provide Ownship state data. AS~~S~~APS **shall** annunciate a failure on loss of any position~~al~~ or velocity data.

2.3 Cockpit Display

TBD

2.4 Equipment Performance—Environmental Conditions

The environmental tests and performance requirements described in this section are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual aeronautical operation.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160E Environmental Conditions and Test Procedures for Airborne Equipment. General information on the use of RTCA/DO-160E is contained in sections 1 through 3 of that document. Also, a method of identifying which environmental tests were conducted and other amplifying information on the conduct of the tests is contained in Appendix A of RTCA/DO-160E.

Some of the performance requirements in section[H20] **Error! Reference source not found.** are not required to be tested to all of the conditions contained in RTCA/DO-160E. Judgment and experience have indicated that these particular parameters are not susceptible to certain environmental conditions and that the level of performance specified in section **Error! Reference source not found.** will not be measurably degraded by exposure to these conditions.

Review of the requirements provided in section **Error! Reference source not found.** indicates that such requirements will be satisfied through software implementations which are not normally affected by environmental conditions. Therefore, the detailed environmental test procedures provided in section 2.4.1.1 are established in order to verify only the various interface functions of the Airborne Surveillance Application

Processing function under environmental conditions. These test procedures are to be performed only for non-integrated Airborne Surveillance Application Processing implementations. When the ASAP implementation is integrated with a TCAS receiver the environmental tests specified in DO-185() are sufficient to validate the environmental performance of ASAP.

2.4.1 **Environmental Test Conditions**[DW21]

Table 2-3aTable 2-3aTable 2-3a lists all of the environmental conditions and test procedures (hereafter referred to as environmental procedures) that are documented in RTCA DO-160E (EUROCAE ED-14E). **Error! Reference source not found.** lists the sets of ASAP performance tests that are specified in detail in this section and which are intended to be performed subject to the various environmental procedures of RTCA DO-160E (EUROCAE ED-14E). Table 2-3aTable 2-3aTable 2-3a divides the environmental procedures into groups. The environmental procedures that apply to all of the sets of ASAP tests fall into group 1. Group 2, which applies to none of the ASAP performance tests, includes only environmental procedures that are intended to determine the effect of the ASAP function on rack mounting hardware, compass needles, explosive gases, and other RF hardware.

Error! Reference source not found. indicates which of the groups of environmental procedures is related to each set of ASAP performance tests. Each ASAP performance test **shall** (R2.1.) be validated under all of the environmental procedures in the groups required for that test as indicated in **Error! Reference source not found.**.

Table 2-3a Environmental Test Groups

Test#	Environmental Condition	RTCA Do-160e Paragraph	EUROCAE Ed-14e Paragraph	ASSAP Groups	CDTI Groups	Remarks
4a	Temperature	4.5	4.4 – 4.5	1	TBD	
4b	Altitude	4.6.1	4.6.1	1		
4c	Decompression & Overpressure	4.6.2 - 4.6.3	4.6.2 - 4.6.3	1		
5	Temperature Variation	5.0	5.0	1		
6	Humidity	6.0	6.0	1		
7a	Operational Shock	7.2	7.1	2~~1~~		
7b	Crash Safety	7.3	7.2	2		NO TESTS
8	Vibration	8.0	8.0	1		During and After
9	Explosion	9.0	9.0	2~~1~~		NO TESTS
10	Waterproofness	10.0	10.0	1		
11	Fluids Susceptibility	11.0	11.0	1		
12	Sand and Dust	12.0	12.0	1		
13	Fungus Resistance	13.0	13.0	1		
14	Salt Spray	14.0	14.0	1		
15	Magnetic Effect	15.0	15.0	2		NO TESTS
16	Power Input Momentary Interruptions All Others	16.0	16.0	1		During and After
17	Voltage Spike	17.0	17.0	2~~1~~		
18	Audio Frequency Conducted Susceptibility	18.0	18.0	1		
19	Induced Signal Susceptibility	19.0	19.0	1		
20	RF Susceptibility	20.0	20.0	1		
21	Emission of RF Energy	21.1	21.1	2		NO TESTS
22	Lightning Induced Transient Susceptibility	22.0	22.0	1		
23	Lightning Direct Effects	23.0	23.0	N/A~~1~~		
24	Icing	24.0	24.0	N/A~~1~~		
25	Electrostatic Discharge	25.0	25.0	2		NO TESTS

Note:

1. *Tests in Group 2 determine the effects of the* ~~STP~~ *ASSAP equipment on other equipment (mounts, compass needles, explosive gases, and other RF equipment) and therefore do not involve the* ~~STP~~*ASSAP equipment performance requirements of this document.*

2. *Environmental test conditions specified in these MOPs are not directly applicable to non-aircraft installations. Manufacturers of such equipment may be permitted to substitute appropriate test standards, such as SAE J1455 (Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy Duty Trucks)).*

Table 2-3b Environmental Test Groups

Test Procedure Paragraph	TEST DESCRIPTION	ASSAPRequired Environmental Test Group		CDTI Environmenta Group
		1		**1**
TBD	TBD	X		
TBD	TBD	X		X
TBD	TBD	X		X

2.4.1.1   Detailed Environmental Test Procedures

The test procedures set forth below are considered satisfactory for use in determining equipment performance under environmental conditions. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternative procedures may be used if the manufacturer can show that they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternative procedures. The ASAP performance tests do not include specific pass/fail criteria. It is intended that those criteria be obtained from the ASAP performance requirements provided in section **Error! Reference source not found.**.

2.4.1.2   TBD

Perform all of the procedures provided in section TBD of this document.

2.4.1.3   TBD

Perform all of the procedures provided in section TBD of this document.

2.4.1.4   TBD

Perform all of the procedures provided in section TBD of this document.

In addition to the exceptions above, certain environmental tests contained in this subsection are not required for minimum performance equipment unless the manufacturer wishes to qualify the equipment for additional environmental conditions. If the manufacturer wishes to qualify the equipment to these additional conditions, then these tests **shall** be performed.

Use only those tests, listed below, that are necessary to assure proper operation in the aeronautical environments envisioned by the Committee. Paragraph 1.0 of RTCA/DO-160D provides additional information on this subject.

2.5   **CDTI Equipment Performance – Environmental Conditions**

2.5.1   **General Requirements**

TBD

2.5.2   **Specific Requirements (?)**

2.6   **ASSAP Equipment Test Procedures**

2.6.1   **Definition of Standard Conditions of Test**

The following definitions of terms and conditions of tests are applicable to the equipment tests specified herein commencing at §2.6.2:

a. Power Input Voltage - Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage +/- 2 percent. The input voltage shall be measured at the input terminals of the equipment under test.

b. Power Input Frequency

    1. In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency +/- 2 percent.

    2. If the equipment is designed for operation from an AC source of variable frequency (e.g., 300 to 1000 Hz), tests shall be conducted with the input frequency adjusted to within five percent of a selected frequency and, unless otherwise specified, within the range for which the equipment is designed.

c. Accuracy of Test Equipment - Throughout this section, the accuracy of the test equipment is not addressed in detail, but rather is left to the calibration process prescribed by the agency which certifies the testing facility.

d. Adjustment of Equipment - The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests. Unless otherwise specified, adjustments may not be made once the test procedures have started.

e. Test Instrument Precautions - During the tests, precautions shall be taken to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments, across the input and output terminals of the equipment under test.

f. Ambient Conditions - Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure and humidity. However, the room temperature shall not be lower than 10 degrees C.

g. Connected Loads - Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance values for which it is designed.

2.6.2   Verification of ASSAP Input/Output Requirements (§2.2.2)

This section will use the reports generated in Section 2.6.5 as stimuli for the ADS-B, ADS-R, TIS-B, TCAS and ownship data.

2.6.2.1   Verification of ADS-B / ADS-R / TIS-B Input Data (2.2.2.1)

Test Procedure:

Step 1. Inject Scenario 1-1 from section 2.6.5.1 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used. Ensure ASSAP is configured to provide all available data to the CDTI interface.

Verify that the appropriate tracks appears on the CDTI interface and the extrapolation of that track is consistent with the truth data. Verify that the Traffic ID/Status data for the track appears on the CDTI interface.

Step 2. Inject Scenario 1-2 from section 2.6.5.1 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify that the appropriate tracks appear on the CDTI interface and the extrapolation of that track is consistent with the truth data. Verify that the Traffic ID/Status data for the track appears on the CDTI interface.

2.6.2.2   Verification of TCAS Input Data (2.2.2.2)

Step 1. Inject Scenario 1-3 from section 2.6.5.1 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation.

Verify that the appropriate TCAS information appears on the CDTI interface.

2.6.2.3   Verification of Ownship Input Data (2.2.2.3)

Step 1. Inject Scenario 1-4 from section 2.6.5.1 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation.

Verify that appropriate ownship data appears on the CDTI interface.

2.6.2.4   **Verification of CDTI Input Data (2.2.2.4)**

2.6.2.5   **Verification of CDTI Output Data (2.2.2.5)**

Test Procedure:

Step 1. Inject Scenario 4-1 Groups 1, 2 & 3 (for ADS-B, ADS-R, TIS-B, & TIS-B data) from section 2.6.5.4 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify ASSAP outputs all required CDTI output data items as listed in Section 2.2.2.5.

2.6.3   **Verification of Surveillance Processing (§2.2.3)**

No specific test procedure is required to validate §2.2.3.

2.6.3.1   **Verification of Source Level Track Generation (§2.2.3.1)**

*Note: Source tracks do not include TCAS tracks (**Test requirement needed**).*

Test Procedure:

Step 1. Inject Scenario 4-1 from section 2.6.5.4 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify all reports result in source level track initiation or track update as appropriate.

2.6.3.1.1   **Verification of Track Estimation (§2.2.3.1.1)**[j22]

Test Tool Requirements:

This test will require the generation of scenarios using the data in table ##, in Appendix ##. It will also require a test tool for measuring track estimate output rates.

Test Procedure:

Devise a method of measuring the output rate for track estimates. Generate scenario(s) using the data in table ##. Be sure to allow 25 second gaps in the ADS-B message flow to force track estimation and measure the track estimate output rate for each target in the Scenario. Verify that the rates equal or exceed one estimate per second for each of the test targets.

Using these same generated scenario(s), verify that all of the track estimates made during the course of the scenario are no worse than a straight line projection from the last received position and velocity with the values in table ## to include target horizontal

position, altitude, and horizontal position accuracy indicators and also ensure that these parameters are estimated to a common time of applicability for all tracks.

2.6.3.2   Verification of Inter-source Correlation (§2.2.3.2)

No specific test procedure is required to validate §2.2.3.2.

2.6.3.2.1   Verification of Correlation of ADS-B, ADS-R, and TIS-B Tracks (§2.2.3.2.1)

Test Procedure::

Step1. Inject Scenario 1-1 from section 2.6.5.1 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. The TCAS report file is not used.

After [x] seconds have elapsed since first update is received from either source, verify there are no missed correlations between ADS-B and TIS-B for track 1A

Step 2. Inject Scenario 2-2 from Section 2.6.5.2 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. The TCAS report file is not used.

Verify there are no (i.e., false) correlations between ADS-B and TIS-B for track 2A

Step 3. Inject Scenario 3-2 from Section 2.6.5.3 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. The TCAS report file is not used.

Verify there are no (i.e., false) correlations between ADS-B and TIS-B for track 3A

Step 4. Inject Scenario 4-1 from section 2.6.5.4 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. The TCAS report file is not used.

Verify all reports correlate with the correct source track.

2.6.3.2.2   Verification of Correlation of TIS-B with Ownship (§2.2.3.2.2)

Test Procedure::

Step1. Inject Scenario 1-4 from section 2.6.5.1 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify there are no missed correlations between TIS-B and ownship

Step 2. Inject Scenario 2-1 from Section 2.6.5.2 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify there are no (i.e., false) correlations with TIS-B and ownship

Step 3. Inject Scenario 3-1 from Section 2.6.5.3 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify there are no (i.e., false) correlations with TIS-B and ownship

2.6.3.2.3 **Verification of Correlation of TCAS with ADS-B, ADS-R, and TIS-B Tracks (§2.2.3.2.3)**

Test Procedure::

Step 1. Inject Scenario 1-1 from section 2.6.5.1 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation.

Verify there are no missed correlations between ADS-B and TCAS for track 1A

Step 2. Inject Scenario 1-2 from section 2.6.5.1 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation.

Verify there are no missed correlations between ADS-R and TCAS for track 1A

Step 3. Inject Scenario 1-3 from section 2.6.5.1 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation.

Verify there are no missed correlations between TIS-B and TCAS for track 1A

Step 4. Inject Scenario 2-2 from Section 2.6.5.2 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation.

Verify there are no (i.e., false) correlations between ADS-B and TCAS for track 2A until the converging track (2B) closes within [1] NM

Step 5. Inject Scenario 3-2 from Section 2.6.5.3 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation.

Verify there are no (i.e., false) correlations between ADS-B and TCAS for track 3A until the climbing track is within [500'] vertically

2.6.3.3 **Verification of Best Source Selection (§2.2.3.3)**

Test Tool Requirements:

This test will require the generation of targets from at least 2 sources as well as from a TCAS source as a prerequisite.

Test Procedure:

Case 1: Generate a track from each source for a single target and give a high SIL value to one of the source tracks. Verify that the source track with the highest SIL value is selected.

Case 2: Generate a track from each source for a single target and have all the SIL values below the minimum threshold for performing the Enhanced Visual Acquisition application. Give one source track a higher NIC value and verify that this source track is selected.

Case 3: Generate a track from each source with SIL and NIC values below the minimum threshold for performing the Enhanced Visual Acquisition application. Give one source track a higher NACp and verify that this source track is selected.

Case 4: Generate a track from each source with SIL, NIC and NACp values below the minimum threshold for performing the Enhanced Visual Acquisition application. Give one source track a higher NACv and verify that this source track is selected.

Case 5: Generate a track from each source with SIL, NIC, NACp and NACv values below the minimum threshold for performing the Enhanced Visual Acquisition application. Generate a TCAS track for the same target and verify that the TCAS track is selected.

2.6.3.4 Verification of Track Termination (§2.2.3.4)

Test Procedure:

Step 1. Inject Scenario 4-1 from section 2.6.5.4 as stimulus to ASSAP including ownship trajectory. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Identify all scenario input tracks that end during the scenario and verify that ASSAP terminates each of these tracks within the maximum coast interval of the final update.

2.6.4 Verification of Application Processing (§2.2.4)

No specific test procedure is required to validate §2.2.4.

2.6.4.1 Verification of General Requirements (§2.2.4.1)

[are there any general requirements now?]

2.6.4.1.1 ASSAP Processing Latency (2.2.4.1)

Test Procedure:

Step 1. Inject Scenario 4-1 Group 1 (for ADS-B & TCAS data) from section 2.6.5.4 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify ASSAP processes ADS-B reports & TCAS data and outputs correlated tracks within 2.0 second latency requirement.

Step 2. Inject Scenario 4-1 Groups 1, 2 & 3 (for ADS-R & TIS-B data) from section 2.6.5.4 as stimulus to ASSAP. Use 1090ES or UAT report format as appropriate for the installation. If ASSAP equipment will not support TCAS, then the TCAS report file is not used.

Verify ASSAP processes ADS-R & TIS-B reports and outputs correlated tracks within 2.0 second latency requirement.

2.6.4.1.2 CDTI Processing Latency (2.2.4.1)

Test Procedure: Inject reports into ASSAP and use ASSAP output as stimulus for CDTI.

Step 1. Inject Scenario 4-1 Group 1 (for ADS-B & TCAS data) from section 2.6.5.4 as stimulus to ASSAP/CDTI. Use 1090ES or UAT report format as appropriate for the installation. If CDTI equipment will not support TCAS, then the TCAS report file is not used.

Verify CDTI correctly processes ADS-B and TCAS tracks and displays traffic data within 0.5 second latency requirement.

Step 2. Inject Scenario 4-1 Groups 1, 2 & 3 (for ADS-R & TIS-B data) from section 2.6.5.4 as stimulus to ASSAP/CDTI. Use 1090ES or UAT report format as appropriate for the installation. If CDTI equipment will not support TCAS, then the TCAS report file is not used.

Verify CDTI correctly processes ADS-R and TIS-B tracks and displays traffic data within 0.5 second latency requirement.

2.6.4.2 Verification of Application-Specific Requirements (§2.2.4.2)

No specific test procedure is required to validate §2.2.4.2.

2.6.4.2.1 Verification of Enhanced Visual Acquisition (EVAcq) (§2.2.4.2.1)

No specific test procedure is required to validate §2.2.4.2.1.

2.6.4.2.1.1 Verification of Ownship Requirements for EVAcq (§2.2.4.2.1.1)

Test Tool Requirements:

This test will require a source for the generation of Own-ship data, a pressure altitude source and a CDTI Display

Test Procedure:

Case 1: Generate Own-Ship data with the Own-ship horizontal position invalid and verify that ASSAP signals that EVAcq is inoperative via the CDTI interface.

Case 2: Generate Own-Ship data with the Own-ship horizontal position accuracy parameter greater than 1.0 Nm and verify that ASSAP signals that EVAcq is inoperative via the CDTI interface.

Case 3: Generate Own-Ship data with the Own-ship pressure altitude invalid and verify that the relative altitude tags are not displayed.

2.6.4.2.1.2 Verification of Target Vehicle Requirements for EVAcq (§2.2.4.2.1.2)

Test Tool Requirements:

This test will require the generation of multiple target scenarios as a prerequisite.

Test Procedure:

Case 1: Generate a scenario with a track that initially has NACp greater than or equal to 4. Have the NACp value drop below 4. Verify that the track is dropped from the CDTI at this time.

Case 2: Generate a scenario with a track that initially has NUC greater than or equal to 3. Have the NUC value drop below 3. Verify that the track is dropped from the CDTI at this time.

Case 3: Generate a scenario with a track that initially has NACp greater than or equal to 4. Update this track in 24 seconds and verify that the track remains on the CDTI. Update the track again in 25 seconds and verify that the track was dropped prior to the second update.

Case 4: Generate a scenario with a track that initially has NUC greater than or equal to 3. Update this track in 24 seconds and verify that the track remains on the CDTI. Update the track again in 25 seconds and verify that the track was dropped prior to the second update.

2.6.4.2.2 **Verification of Airport Surface Situational Awareness/Final Approach and Runway Occupancy Awareness (ASSA/FAROA) (§2.2.4.2.2)**

No specific test procedure is required to validate §2.2.4.2.2.

2.6.4.2.2.1 **Verification of Ownship Requirements for ASSA/FAROA (§2.2.4.2.2.1)**

Note: Revisit altitude source issues after geo altitude action is resolved

Test Tool Requirements:

This test will require a source for the generation of Own-ship data.

Test Procedure:

Case 1: Generate Own-Ship data with the Own-ship horizontal position invalid and verify that ASSAP signals that ASSA/FAROA is inoperative via the CDTI interface.

Case 2: Generate Own-Ship data, in the airborne state, with the Own-ship vertical position invalid and verify that ASSAP signals that ASSA/FAROA is inoperative via the CDTI interface.

Case 3: Generate Own-Ship data, in the on-ground state, with the Own-ship vertical position invalid and verify that ASSAP signals that ASSA/FAROA is operative via the CDTI interface.

Case 4: Generate Own-Ship data with the Own-ship SIL set to zero and verify that ASSAP signals that ASSA/FAROA is inoperative via the CDTI interface.

Case 5: Generate Own-Ship data with the Own-ship Radius of containment greater than 0.1 Nm and verify that ASSAP signals that ASSA/FAROA is inoperative via the CDTI interface.

Case 6: Generate Own-Ship data with the Own-ship position accuracy greater than 0.04 Nm and verify that ASSAP signals that ASSA/FAROA is inoperative via the CDTI interface.

2.6.4.2.2.2 **Verification of Target Vehicle Requirements for ASSA/FAROA (§2.2.4.2.2.2)**

Test Tool Requirements:

This test will require the generation of multiple target scenarios as a prerequisite.

Test Procedure:

Case 1: Generate a scenario with a 1090ES Version 0 surface track that initially has NUC value of 6. Verify that the track is not marked as a valid ASSA/FAROA target. Increase

the NUC value to 7 and verify that the track is now marked as a valid ASSA/FAROA target.

Case 2: Generate a scenario with a 1090ES Version 1 surface track that initially has NACp value of 7, a NIC value of 8 and a SIL value of 1. Include a second track that initially has a NACp value of 8, a NIC value of 7 and a SIL of 1 and a third track that initially has a NACp value of 8, a NIC value of 8 and a SIL of 0. Verify that none of the three tracks are marked as valid ASSA/FAROA targets. Increase the NACp of track 1 to a value of 8, the NIC of track 2 to 8 and the SIL of track 3 to 1 and verify that all three tracks are now marked as valid ASSA/FAROA targets. Repeat this case for UAT tracks.

Case 3: Generate a scenario with a 1090ES Version 0 airborne track that initially has NUC value of 7 and Verify that the track is marked as a valid ASSA/FAROA target. Reduce the NUC value to 3 and verify that the track remains on the CTDI interface. Now reduce the NUC value to 2 and verify that the track is dropped from the CDTI interface.

Case 4: Generate a scenario with a UAT Version 1 airborne track that initially has NACp value of 8 and Verify that the track is marked as a valid ASSA/FAROA target. Reduce the NACp value to 4 and verify that the track remains on the CTDI interface. Now reduce the NACp value to 3 and verify that the track is dropped from the CDTI interface.

Case 5: Generate a scenario with a moving ASSA/FAROA track. Allow 11 seconds to pass before the track is updated and verify that the track is still marked as a valid ASSA/FAROA track. Allow a further 12 seconds to pass before the track is updated and verify that the track is now marked as an invalid ASSA/FAROA track.

Case 6: Generate a scenario with a stationary ASSA/FAROA track. Allow 15 seconds to pass before the track is updated and verify that the track is still marked as a valid ASSA/FAROA track. Allow a further 16 seconds to pass before the track is updated and verify that the track is now marked as an invalid ASSA/FAROA track.

2.6.4.2.2.3   Verification of Conflict Detection (CD) (§2.2.4.2.2.3)

Test Tool Requirements:

This test will require the generation of multiple target scenarios as a prerequisite.

Test Procedure:

Case 1: Generate a scenario with a track that is eligible for CD that is in a CAZ alert situation. Verify that a CAZ alert was issued for this track and that the status of this CAZ alert was reflected in the ASSAP track report.

Case 2: Generate a scenario with a track that is eligible for CD that is in a CDZ alert situation. Verify that a CDZ alert was issued for this track and that the status of this CDZ alert was reflected in the ASSAP track report.

2.6.4.2.2.3.1   Verification of Ownship Requirements for CD (§2.2.4.2.2.3.1)

Test Tool Requirements:

This test will require a source for the generation of Own-ship data.

Test Procedure:

Case 1: Generate Own-Ship data with the Own-ship horizontal position invalid and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 2: Generate Own-Ship data, in an airborne state, with the Own-ship vertical position invalid and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 3: Generate Own-Ship data with the Own-ship horizontal position uncertainty set greater than 0.5NM and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 4: Generate Own-Ship data, in the airborne state using HAE for vertical position where the vertical position uncertainty is set greater than 45m, and verify that ASSAP signals that CD is operative via the CDTI interface.

Case 5: Generate Own-Ship data with the Own-ship horizontal velocity uncertainty set greater than 3m/s and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 6: Generate Own-Ship data with the Own-ship Radius of containment greater than 1 NM and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 7: Generate Own-Ship data with the Own-ship Integrity Containment Risk set greater than 10^{-2}/hr and verify that ASSAP signals that CD is inoperative via the CDTI interface.

2.6.4.2.2.3.2   Verification of Target Vehicle Requirements for CD (§2.2.4.2.2.3.2)

A target track **shall** (R2.xxx) have a NACv of 2 or greater to be marked as a valid CD target.

A target track **shall** (R2.xxx) have a SIL of 0 (10^{-2}/hr) or greater and a NIC of 5 or greater to be marked as a valid CD target.

If a CD target is not updated within 30 seconds, ASSAP **shall** (R2.xxx) mark the target as invalid for the Conflict Detection application.

Test Tool Requirements:

This test will require the generation of target tracks.

Test Procedure:

Case 1: Generate target data with a valid horizontal and vertical position and verify that ASSAP signals that a CD target is derived via the CDTI interface.

Case 2: Generate target data with a pressure source for altitude and a NACp value set to 4 and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 3: Generate target data with a pressure source for altitude and a NACp value set to 5 and verify that ASSAP signals that a CD target is derived via the CDTI interface.

Case 4: Generate target data with an HAE source for altitude and a NACp value set to 8 and verify that ASSAP signals that CD is inoperative via the CDTI interface.

Case 5: Generate target data with an HAE source for altitude and a NACp value set to 9 and verify that ASSAP signals that a CD target is derived via the CDTI interface.

2.6.4.2.2.4 Verification of Enhanced Visual Approach (EVApp) (§2.2.4.2.2.4)

No specific test procedure is required to validate §2.2.4.2.2.4.

2.6.4.2.2.4.1 Verification of Ownship Requirements for EVApp (§2.2.4.2.2.4.1)

Test Tool Requirements:

This test will require a source for the generation of Own-ship data.

Test Procedure:

Case 1: Generate Own-Ship data with the Own-ship horizontal position invalid and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 2: Generate Own-Ship data, in an airborne state, with the Own-ship vertical position invalid and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 3: Generate Own-Ship data with the Own-ship horizontal position uncertainty set greater than 0.1 NM and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 4: Generate Own-Ship data, in the airborne state using HAE for vertical position where the vertical position uncertainty is set greater than 45m, and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 5: Generate Own-Ship data with the Own-ship horizontal velocity uncertainty set greater than 10m/s and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 6: Generate Own-Ship data with the Own-ship Radius of containment greater than .2 NM and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 7: Generate Own-Ship data with the Own-ship Integrity Containment Risk set greater than 10^{-3}/hr and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

2.6.4.2.2.4.2 Verification of Target Vehicle Requirements for EVApp (§2.2.4.2.2.4.2)

TBD versions of existing ADS-B links are eligible to be EVAPP targets (e.g., DO-260 Version 0).

An EVApp target **shall** (R2.xxx) be derived from a target track with valid horizontal and vertical position. Vertical position is satisfied by Height Above the Ellipsoid (HAE) or pressure altitude. When pressure altitude is used for vertical position, a target track **shall** (R2.xxx) have a NACp of 7 or greater to be marked as a valid EVApp target. When HAE is used for vertical position, a target track **shall** (R2.xxx) have a NACp of 9 or greater to be marked as a valid EVApp target.

A target track **shall** (R2.xxx) have a NACv of 1 or greater to be marked as a valid EVApp target.

A target track **shall** (R2.xxx) have a SIL of 1 or greater and a NIC of 7 or greater to be marked as a valid EVApp target.

If an EVApp target is not updated within 15 seconds, ASSAP **shall** (R2.xxx) mark the target as invalid for the Enhanced Visual Approach application.

Test Tool Requirements:

This test will require the generation of target tracks.

Test Procedure:

Case 1: Generate target data with a valid horizontal and vertical position and verify that ASSAP signals that a EVApp target is derived via the CDTI interface.

Case 2: Generate target data with a pressure source for altitude and a NACp value set to 6 and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 3: Generate target data with a pressure source for altitude and a NACp value set to 7 and verify that ASSAP signals that a EVApp target is derived via the CDTI interface.

Case 4: Generate target data with an HAE source for altitude and a NACp value set to 8 and verify that ASSAP signals that EVApp is inoperative via the CDTI interface.

Case 5: Generate target data with an HAE source for altitude and a NACp value set to 9 and verify that ASSAP signals that a EVApp target is derived via the CDTI interface.

2.6.4.3   **Verification of Monitoring (§2.2.4.3)**

No specific test procedure is required to validate §2.2.4.3.

2.6.4.3.1   **Verification of General Requirements (§2.2.4.3.1)**

No specific test procedure is required to validate §2.2.4.3.1.

2.6.4.3.1.1   **Verification of Self Test (§2.2.4.3.1.1)**

The manufacturer shall provide a test plan to verify that the self-test function operates as specified in subparagraph 2.2.4.3.1.1. The general considerations stated in subparagraph TBD for performance monitoring apply. Procedures for self-test verification may, whenever appropriate, use the results of tests performed under subparagraph TBD for performance monitoring.

2.6.4.3.1.2   **Verification of Non Interference (§2.2.4.3.1.2)**

No verification requirements or test procedures required? (None in TCAS MOPS DO-185A)

2.6.4.3.2   **Verification of Monitoring of ASAS Computer Resources (§2.2.4.3.2)**

The verification of ASAS computer resources shall include the following items:

1. RAM pattern tests – the manufacturer shall verify RAM by writing unique patterns of 1's and 0's into RAM and then read these values back out of RAM to check for bad bits. Each memory bit shall be verified using both 0's and 1's.

2. CPU instruction tests – the manufacturer shall verify that CPU instructions are correct and functional (i.e., not corrupted).

3. Program memory tests – the manufacturer shall verify that the software program contained in program memory is as originally loaded. (i.e., has not been corrupted)

4. Input/Output Tests – the manufacturer shall verify all ASAS I/O functions.

5. Timing Tests – the manufacturer shall verify that all CPU's, microcontrollers and other devices utilizing a clock input operate within their allowable timing constraints as established by each device's manufacturer.

2.6.4.3.3   **Verification of ASAS Input Data Monitoring (§2.2.4.3.3)**

No specific test procedure is required to validate §2.2.4.3.3.

2.6.4.3.3.1 Verification of ADS-B Receive Subsystem (§2.2.4.3.3.1)

Note: This could be accomplished though a periodic heartbeat message that would indicate function in the absence of traffic

The manufacturer shall verify the ADS-B receive monitor per the following procedure:

1. Provide ADS-B receive data into the ASAP function, either via a real unit or a simulated data stream. Interrupt the ADS-B receive data into ASAP and verify the annunciation of loss of ADS-B receive data.

2. Provide ADS-B receive data into the ASAP function, either via a real unit or a simulated data stream. Corrupt the ADS-B receive reports into ASAP and verify the annunciation of loss of ADS-B receive data.

2.6.4.3.3.2 Verification of TCAS (§2.2.4.3.3.2)

The manufacturer shall verify the TCAS monitor per the following procedure:

1. Provide TCAS data into the ASAP function, either via a real unit or a simulated data stream. Interrupt the TCAS data into ASAP and verify the annunciation of loss of TCAS data.

2. Provide TCAS data into the ASAP function, either via a real unit or a simulated data stream. Corrupt the TCAS data words into ASAP and verify the annunciation of loss of TCAS data.

2.6.4.3.3.3 Verification of Ownship State Data (§2.2.4.3.3.3)

The manufacturer shall verify the ownship data monitor per the following procedure:

1. Provide ownship data into the ASAP function, either via a real unit or a simulated data stream. Interrupt the ownship data into ASAP and verify the annunciation of loss of ownship data.

2. Provide ownship data into the ASAP function, either via a real unit or a simulated data stream. Corrupt the ownship data words into ASAP and verify the annunciation of loss of ownship data.
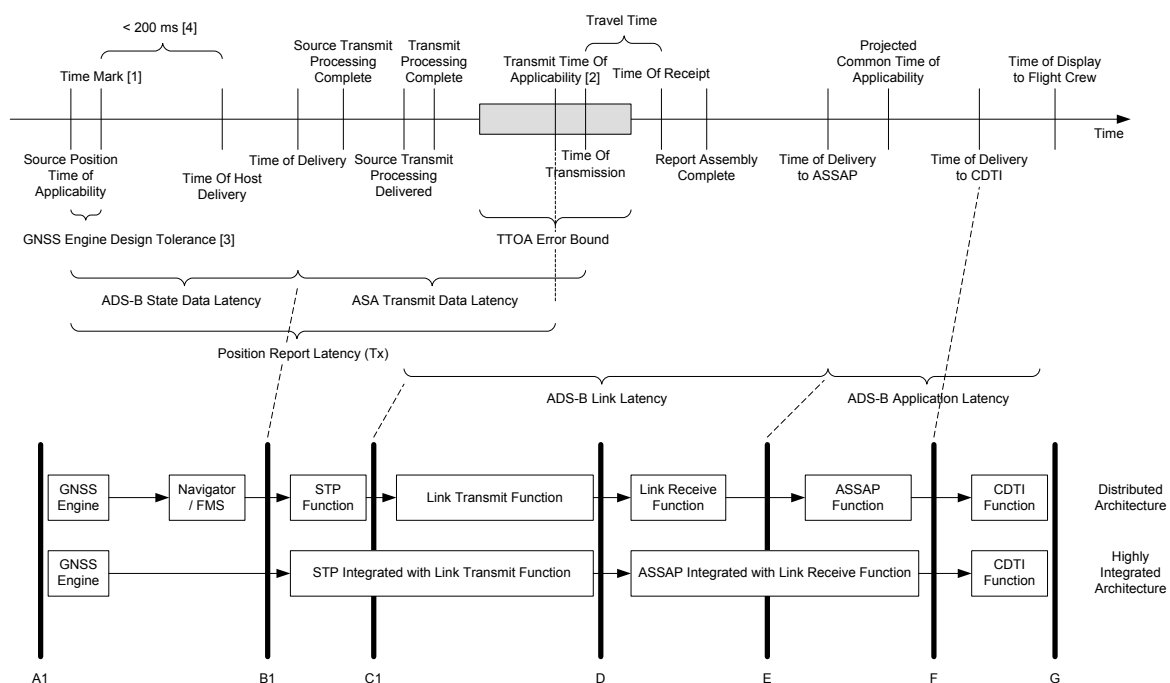
Figure 2-6 ADS-B Latency Definitions
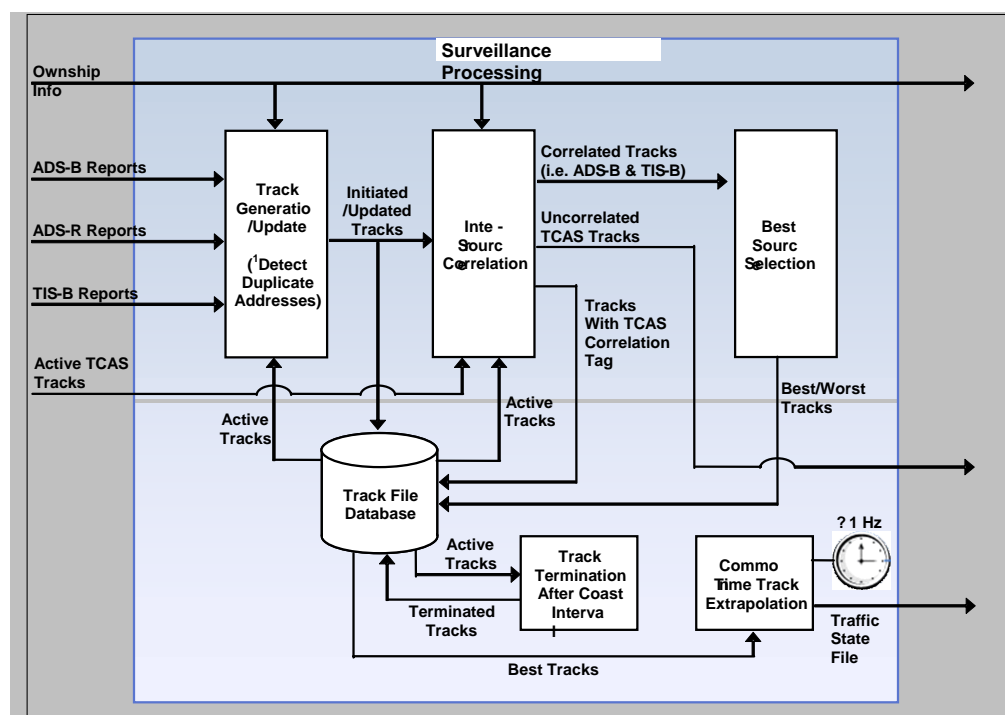
Figure 2-7 CDTI Equipment Test Procedures

2.6.5   **Description of Test Scenarios Used as ASSAP Test Stimulus**

This appendix describes specific aircraft trajectory sets that are used to provide stimulus scenarios for ASSAP testing. Four trajectory sets are used, where each trajectory set is designed to stress specific ASSAP requirements. For each trajectory set, multiple scenarios are created by assigning various sources to each trajectory. Each source is simulated by taking the idealized truth trajectory and adding position noise. For ADS-B and ADS-R this position noise is consistent with a NACp = 5 since that's the minimum NACp for any application. For TIS-B and TCAS, position noise applied is appropriate for the source where these sources have been characterized based on flight data. The final step is to down sample the trajectory to simulate ADS-B media access operation and expected link reception performance. Air-air link performance (for ADS-B and TCAS) is based on flight data and ground-air link performance (ADS-R and TIS-B) is based on performance requirements in the SBS Specification.

The process used in converting the idealized track data to the reports used as stimulus for ASSAP testing is detailed in Appendix [LarryB?]. The resulting report files associated with each scenario are provided in separate media in individual files with a report format defined in Appendix [LarryB]. Finally, it should be noted that each scenario can actually result in up to 4 separate stimulus files depending on the installed environment for ASSAP. This is necessary to accommodate differences in report generation between 1090ES and UAT receivers and to accommodate differences in installations with and without support for TCAS.

Additional conditions/assumptions for all scenarios:

- TIS-B reports will contain a track number as generated by the ground system. This track number will remain constant throughout each trajectory

- ASSAP is being driven by a single link receiver: i.e., ADS-B/ADS-R do not occur simultaneously on the same target.

2.6.5.1   **Trajectory Set #1: Check for Missed Correlations**

- Trajectory Set #1 is designed to ensure missed correlations do not happen. It uses 2 simultaneous aircraft trajectories. Figure 2-8 shows the trajectories.

- Trajectory 1A is a level 180 degree turn at 6 degrees per second with a speed of 200 kts.

- Trajectory 1B is a close by track to serve as ownship.

- TCAS track does NOT include Mode S address
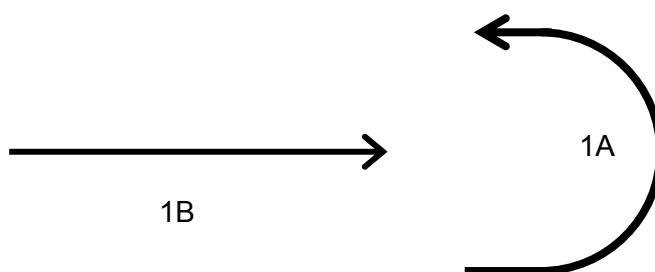
Figure 2-8 Trajectory Set #1

Table 2-4 below shows the specific stimulus scenarios that are generated by assigning various sources to each trajectory.

Table 2-4 Scenarios Generated from Trajectory Set #1

Scenario #	Ownship Track	Ownship TIS-B	Target Track	Target Sources				Criteria
				ADS-B	ADS-R	TIS-B	TCAS	
1-1	1B		1A	√		√	√	Ensure no missed ADS-B, TIS-B and TCAS correlations for target
1-2	1B		1A		√		√	Ensure no missed ADS-R and TCAS correlations for target.
1-3	1B		1A			√	√	Ensure no missed TIS-B and TCAS correlations for target.
1-4	1A	√	N/A					Ensure no missed TIS-B and ownship correlations.

2.6.5.2   **Trajectory Set #2: Check for False Correlations due to Horizontal Closure**

Trajectory Set #2 is designed to ensure false correlations due to closure in the horizontal plane do not happen. It uses 3 simultaneous aircraft trajectories as shown in Figure 2-9:

- Trajectory 2A is a level unaccelerated track at 200 kts.

- Trajectory 2B is a level track, coaltitude with 2A and converging with 2A at a 30 degree intercept (the intercept includes a turn anticipation consistent with a standard rate turn with no overshoot). Trajectories 2A and 2B begin 2 NM separated and are actually coincident from the intercept point through the remainder of the trajectory.

- Trajectory 2C is a close by track to serve as ownship in trail of 2A by 10 NM

- TCAS track does NOT include Mode S address

Converging Track (2B)

30°

In Trail Track (2C)

Unaccelerated Track (2A)
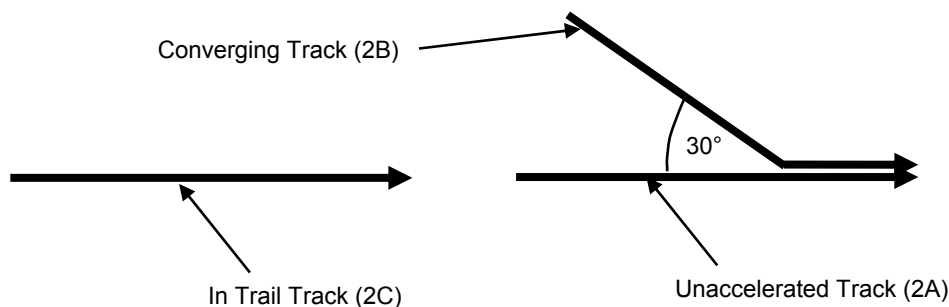
Figure 2-9 Trajectory Set 2

Table 2-5 below shows the specific stimulus scenarios that are generated by assigning various sources to each trajectory.

Table 2-5 Scenarios Generated by Trajectory Set #2

Scenario #	Ownship Track	Ownship TIS-B	Target Track	Target Sources				Criteria
				ADS-B	ADS-R	TIS-B	TCAS	
2-1	2A		2B	√		√	√	Ensure ADS-B, TIS-B and TCAS all correlate for target and that TIS-B on target does not falsely correlate to ownship.
2-2	2C		2A	√		√	√	Ensure no missed or false correlations of TCAS for targets prior to [1] NM closure of 2B with 2A and for TIS-B at all times
			2B			√	√	

2.6.5.3   Trajectory Set #3: Check for False Correlations due to Vertical Closure

Trajectory Set #3 is designed to ensure false correlations due to closure in the vertical plane do not happen. It uses 3 aircraft trajectories as shown in Figure 2-10.

- Trajectory 3A is a level unaccelerated track at 150 kts.

- Trajectory 3B is a climbing track at a 1000 fpm rate also at 150 kts and converging with 3A at an intercept point. Trajectory 3A and 3B start out with 2000' vertical separation. Trajectory 3B levels out and is actually coincident with 3A for the remainder of the trajectory.

- Trajectory 3C is a close by track to serve as ownship in trail of 3A by 10 NM

- TCAS track does NOT include Mode S address
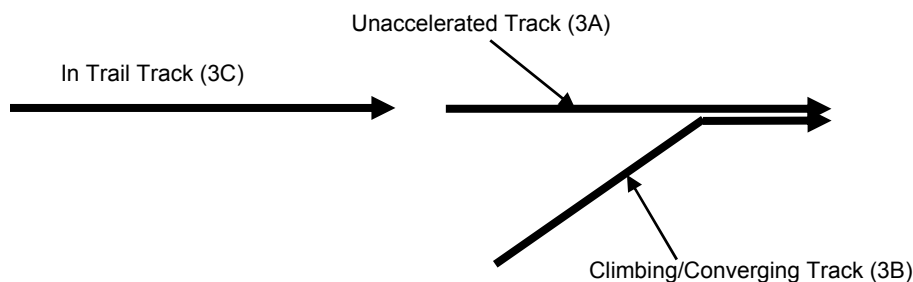
Figure 2-10 Trajectory Set #3

Table 2-6 below shows the specific stimulus scenarios that are generated by assigning various sources to each trajectory.

Table 2-6 Scenarios Generated from Trajectory Set #3

Scenario #	Ownship Track	Ownship TIS-B	Target Track	ADS-B	ADS-R	TIS-B	TCAS	Criteria
				Target Sources				**Criteria**
3-1	3A		3B	√		√	√	Ensure ADS-B, TIS-B and TCAS all correlate for target and that TIS-B on target does not falsely correlate to ownship.
3-2	3C		3A	√		√	√	Ensure no missed or false correlations of TCAS for targets prior to [500'] closure of 3B with 3A and for TIS-B at all times
			3B			√	√	

2.6.5.4   Trajectory Set #4: Check Track Capacity, Track Generation and Track Termination

Trajectory Set #4 is based on about 12 minutes of radar data from the Atlanta Terminal Radar (60 NM radius from ATL) recorded in August 2006 around 4:30 pm local time. Approaches to 3 simultaneous parallel runways are in use (RWYS 08L, 09R, 10). Figure 2-11 below shows the main flows evident in the data. Other traffic due to overflights and operations to nearby airports are also evident but account for a relatively small fraction of the total number of trajectories.
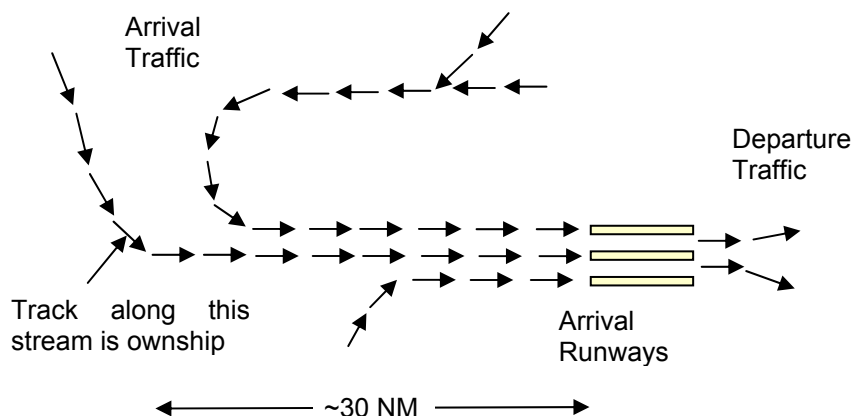
Figure 2-11 Main Flows of Trajectory Set #4

A single track (identified as track # 227 in the data set) along the center approach path is selected as the ownship. In order to create the scenario, the [120] individual trajectories in the data are partitioned into groups by the surveillance source applicable as shown in Table 2-7 below. <mark>[One half] of TCAS tracks are selected at random to INCLULDE a Mode S address; the remaining TCAS tracks will not have a Mode S address</mark>.

Table 2-7 Scenario Generated from Trajectory Set #4

Scenario #	Ownship Track #	Ownship TIS-B	Target Track #	Target Sources				Criteria
				ADS-B	ADS-R	TIS-B	TCAS	
4-1	#227	Y	Group 1	√			√	Ensure no missed or false correlations for any traffic or ownship
			Group 2		√		√	Ensure all tracks are processed appropriately with each update received
			Group 3	√		√	√	Ensure the appropriate (and only the appropriate) tracks terminate

Group 1: 75% of total tracks selected at random
Group 2: 20% of total tracks (selected at random from remaining tracks)
Group 3: 5% of total tracks (all the remaining tracks)

3   INSTALLED EQUIPMENT PERFORMANCE

This section states the minimum acceptable level of performance for the equipment when installed in the aircraft. For the most part, installed performance requirements are the same as those contained in Section 2, which were verified through bench and environmental test. However, certain requirements may be affected by the physical installation (e.g., antenna patterns, receiver sensitivity, etc.) and can only be verified after installation. The installed performance limits stated below take in consideration these situations.

3.1   Equipment Installation

3.1.1   Accessibility

Controls and monitors provided for in-flight operations **shall** be readily accessible from the pilot's normal seated position. The appropriate operator/crew member(s) **shall** have an unobstructed view of displayed data when in the normal seated position.

3.1.2   Aircraft Environment

Equipment **shall** be compatible with the environmental condition present in the specific location in the aircraft where the equipment is installed.

3.1.3   Display Visibility

Display intensity **shall** be suitable for data interpretation under all cockpit ambient light conditions ranging from total darkness to reflected sunlight.

Note: Visors, glare-shields or filters may be an acceptable means of obtaining daylight visibility.

3.1.4   Dynamic Range

Operation of the equipment **shall** not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight conditions.

3.1.5   Failure Protection

Any probable failure of the equipment **shall** not degrade the normal operation of equipment or systems connected to it. Likewise, the failure of interfaced equipment or systems **shall** not degrade normal operation of this equipment.

3.1.6 Interference Effects

The equipment **shall** not be the source of harmful conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

*Note: Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft. The various factors contributing to the incompatibility **shall** be considered.*

3.1.7 Inadvertent Turnoff

Appropriate protection **shall** be provided to avert the inadvertent turnoff of the equipment.

3.1.8 Aircraft Power Source

State any requirements for connecting the equipment to the aircraft power source(s) to assure the equipment will perform its intended function(s) in the operational environment.

3.1.9 Other Requirements

Continue with other requirements concerning equipment installation items such as antenna, etc.

3.2 Installed Equipment Performance Requirements

The installed equipment **shall** meet the requirements of Subsections 2.1 and 2.2 in addition to, or as modified by, the requirements stated below.

State the requirements that the equipment must meet when installed in the aircraft. The following guidelines, although not all inclusive, serve to illustrate some of the more important aspects that should be considered:

a. Requirements should be strictly limited to those that the Committee considers necessary for all applications and user classes.

b. In general, use one paragraph to express a single requirement.

c. Requirements should be expressed in a manner that does not constrain design innovation.

d. Requirements should not place undue constraints on installation flexibility.

e. Care should be taken to define requirements that may be at variance with those stated in Section 2 because of physical or other installation constraints.

f. State those requirements that the equipment must meet to perform its intended function(s) but can only be verified after installation.

g. Unless a requirement can be verified solely through visual inspection, it should be expressed in measurable terms.

h. Particular care must be taken to assure that the requirement statement is compatible with test procedures to be developed for paragraph 3.4.

3.3 Conditions of Test

The following subparagraphs define conditions under which tests, specified in paragraph 3.4, **shall** be conducted.

3.3.1 Safety Precautions

State any personnel and/or equipment safety precautions that should be observed because of any unique characteristics of the equipment or installation.

3.3.2 Power Input

Unless otherwise specified, all aircraft electrically operated equipment and systems **shall** be turned ON before conducting interference testing.

3.3.3 Environment

During testing, the equipment **shall** not be subjected to environmental conditions that exceed those specified by the equipment manufacturer.

3.3.4 Adjustment of Equipment

Circuits of the equipment under test **shall** be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

3.3.5 Warm-up Period

Unless otherwise specified, tests **shall** be conducted after a warm-up (stabilization) period of not more than fifteen (15) minutes.

3.3.6   **Continue with Other Conditions as Necessary**

3.4   **Test Procedures for Installed Equipment Performance**

The following test procedures provide one means of determining installed equipment performance. Although specific test procedures are cited, it is recognized that other methods may be preferred by the installing activity. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures. The equipment **shall** be tested to determine compliance with the minimum requirements stated in Subsection 2.2. In order to meet this requirement, test results supplied by the equipment manufacturer or other proof of conformity may be accepted in lieu of bench tests performed by the installing activity.

3.4.1   **Ground Test Procedures**

3.4.1.1   **Conformity Inspection**

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. Verify that proper mechanical and electrical connections have been made and that the equipment has been located and installed in accordance with the manufacturer's recommendations.

3.4.1.2   **Equipment Function**

Vary all controls of the equipment through their full range to determine that the equipment is operating according to the manufacturer's instruction and that each control performs its intended function.

3.4.1.3   **Interference Effects**

With the equipment energized, individually operate each of the other electrically operated aircraft equipment and systems to determine that significant conducted or radiated interference does not exist. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on the low, high and at least on, but preferably four, mid-band frequencies. Make note of system or modes of operation that should also be evaluated during flight. If appropriate, repeat tests using emergency power with the aircraft's batteries alone and the inverters operating.

3.4.1.4   **Power Supply Fluctuations**

Under normal aircraft conditions, cycle the aircraft engine(s) through all normal power settings and verify proper operation of the equipment as specified by the equipment manufacturer.

3.4.1.5   **Equipment Accessibility**

Determine that all equipment controls and displayed data are readily accessible and easily interpreted.

3.4.1.6   **Continue with Other Test Procedures**

Continue with other test procedures to verify those installed performance requirements of paragraphs 3.1 and 3.2 that can be demonstrated with the aircraft on the ground.

Test Procedure:

1. Connect ramp test set to the input connector(s) of the ASSAP/ CDTI equipment.

2. The installed ASSAP/CDTI equipment shall accept input ADS-B, ADS-R and TIS-B data reports from the ADS-B In receiver or the ramp test set, TCAS tracks from a real or simulated TCAS LRU, and real or simulated ownship data sources as defined in Section 2.2.2.

3. The ASSAP/CDTI equipment shall display all required traffic data elements on the CDTI per the requirements of Section 2.3.

4. All traffic data elements shall be displayed per the requirements of Table 2-1 for target vehicle data and Table 2-2 for ownship data for each of the supported applications.

[NOTE: If end to end latency testing is deleted from this section, where is it tested?]

3.4.2   **Flight Test Procedures**

3.4.2.1   **Displayed Data Readability**

Determine that normal conditions of flight do not significantly affect the readability of displayed data.

3.4.2.2   **ASSAP Installed Flight Test**

~~ADD A SECTION THAT MIMICS SOME OF THE WORDS FROM DO-260A.~~Flight tests are not necessary for functions that encode, communicate and decode messages, assemble reports, or generate display inputs.

APPENDIX A

ACRONYMS AND DEFINITIONS OF TERMS

APPENDIX A ACRONYMS AND DEFINITIONS OF TERMS

A.1   Acronyms

The following acronyms and symbols for units of measure are used in this document.

A/S	Adjacent Ship
A/V	Aircraft/Vehicle
AC	Aviation Circular (FAA)
AC	Aircraft
ACAS	Airborne Collision Avoidance System. (ACAS is the ICAO standard for TCAS)
ACL	ASA Capability Level
ACM	Airborne Conflict Management
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance – Broadcast
AGL	Above Ground Level
AILS	Airborne Information for Lateral Spacing
AIM	Aeronautical Information Manual, (FAA publication)
ALPA	Air Line Pilots Association
AMASS	Airport Movement Area Safety Systems
AMMD	Aerodrome Moving Map Display (an acronym from [DO-257A])
ANSD	Assured Normal Separation Distance
AOC	Aeronautical Operational Control
AOC	Airline Operations Center
AOPA	Aircraft Owners and Pilots Association
APU	Auxiliary Power Unit
ARTCC	Air Route Traffic Control Center
ASA	Aircraft Surveillance Applications (to be distinguished from Airborne-Surveillance Applications which not referenced as ASA in this document)
ASAS	(1) Airborne Separation Assurance System (an acronym used in [PO-ASAS]) or (2) Aircraft Surveillance Applications System (an acronym from [DO-289]). The two terms are equivalent.
ASDE-3	Airport Surveillance Detection Equipment version 3
ASDE-X	Airport Surveillance Detection Equipment X-band
ASF	Air Safety Foundation (AOPA organization)
ASIA	Approach Spacing for Instrument Approaches
ASOR	Allocation of Safety Objectives and Requirements
ASRS	Aviation Safety Reporting Service
ASSA	Airport Surface Situational Awareness
ASSAP	Airborne Surveillance and Separation Assurance Processing
AT	Air Traffic
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automated Terminal Information System
ATM	Air Traffic Management

ATP	Airline Transport Pilot (rating)
ATS	Air Traffic Services
ATSA	Airborne Traffic Situational Awareness
ATSP	Air Traffic Service Provider
BAQ	Barometric Altitude Quality
CAASD	Center for Advanced Aviation System Development
CARE	Co-operative Actions of R&D in EUROCONTROL
CAZ	Collision Avoidance Zone
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CDTI	Cockpit Display of Traffic Information
CDU	Control and Display Unit
CDZ	Conflict Detection Zone
CFR	Code of Federal Regulations
CNS	Communications, Navigation, Surveillance
CP	Conflict Prevention
CPA	Closest Point of Approach
CPDLC	Controller Pilot Data Link Communications
CR	Conflict Resolution
CRM	Crew Resource Management
CSPA	Closely Spaced Parallel Approaches
CTAF	Common Traffic Advisory Frequency
CTAS	Center TRACON Automation System
DAG	Distributed Air Ground
DGPS	Differential GPS
DH	Decision Height
DME	Distance Measuring Equipment
DOT	Department of Transportation, U. S. Government
EMD	Electronic Map Display
EPU	Estimated Position Uncertainty
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
EVAcq	Enhanced Visual Acquisition
EVApp	Enhanced Visual Approach
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FAROA	Final Approach and Runway Occupancy Awareness
FAST	Final Approach Spacing Tool
FFAS	Free Flight Airspace
FIS-B	Flight Information Services – Broadcast
FL	Flight Level
FMEA	Failure Modes and Effects Analysis
FMS	Flight Management System
Fpm	Feet Per Minute
FSDO	Flight Standards District Office (FAA)
FSS	Flight Service Station

Ft	Feet
GA	General Aviation
GHz	Giga Hertz
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	Ground-based Surveillance Application
HAE	Height Above Ellipsoid
HFOM	Horizontal Figure Of Merit
HGS	Head-Up Guidance System
HMI	Hazardously Misleading Information
HPL	Horizontal Protection Limit
HUD	Head-Up Display
Hz	Hertz
ICAO	International Civil Aviation Organization
ICR	Integrity Containment Risk
ICSPA	Independent Closely Spaced Parallel Approaches
ID	Identification
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
JTIDS	Joint Tactical Information Distribution System
LA	Los Angeles
LAAS	Local Area Augmentation System
LAHSO	Land And Hold Short Operations
LL	Low Level
LOS	Loss of Separation
m	meter (or "metre"), the SI metric system base unit for length
MA	Maneuver Advisory
MAC	Midair Collision
MACA	Midair Collision Avoidance
MAS	Managed Airspace
MASPS	Minimum Aviation System Performance Standards
MCP	Mode Control Panel
MFD	Multi-Function Display
MHz	Mega Hertz
Mm	Millimeter
MOPS	Minimum Operation Performance Standards (RTCA documents)
Mrad	milliradian. 1 mrad = 0.001 radian
MTTF	Mean Time To Failure
N/A	Not Applicable or No Change
NAC	Navigation Accuracy Category (sub "p" is for position and sub "v" is for velocity)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
ND	Navigation Display

NIC	Navigation Integrity Category
NLR	Nationaal Luchten Ruimtevaartlaboratorium (National Aerospace Laboratory in the Netherlands)
NM	Nautical Mile
NMAC	Near Mid Air Collision
NMPH	Nautical Miles Per Hour
NOTAM	NOTice to AirMen
NPA	Non-Precision Approach
NSE	Navigation System Error
NTSB	National Transportation Safety Board
O/S	Ownship
OH	Operational Hazard
OHA	Operational Hazard Assessment
OPA	Operational Performance Assessment
OSA	Operational Safety Analysis
OSED	Operational Services and Environment Description
OTW	Out-the-Window
PA	Prevention Advisory
PAPI	Precision Approach Path Indicator
PAZ	Protected Airspace Zone
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
PO-ASAS	Principles of Operation for the Uses of ASAS (See the entry in DO-189 Appendix-B for [PO-ASAS])
PRM	Precision Runway Monitor
PSR	Primary Surveillance Radar
R&D	Research and Development
RA	Resolution Advisory (TCAS II),
rad	radian, an SI metric system derived unit for plane angle
RAIM	Receiver Autonomous Integrity Monitoring
RC	Radius of Containment
REQ No.	Requirement Number
RIPS	Runway Incursion Prevention System
RMS	Root Mean Square
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTA	Required Time of Arrival
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minimum
rx	receive, receiver
s	second, the SI metric system base unit for time or time interval
SAE	Society of Automotive Engineers
SC	Special Committee
SF21	Safe Flight 21
SGS	Surface Guidance System

SI	Système International d'Unités (International System of Units not to be confused with the Mode Select Beacon system SI function)
SIL	Surveillance Integrity Level (sub BARO is for barometric altitude)
SIRO	Simultaneous Intersecting Runway Operations
SM	Statute Miles
SMM	Surface Moving Map
SPR	Surveillance Position Reference point
SSR	Secondary Surveillance Radar
STP	Surveillance Transmit Processing
SV	State Vector
SVFR	Special Visual Flight Rules
TA	Traffic Advisory (TCAS II)
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Alert and Collision Avoidance System (See ACAS)
TCAS I	TCAS system that does not provide resolution advisories
TCAS II	TCAS system that provides resolution advisories
TCP	Trajectory Change Point
TCV	Test Criteria Violation
TESIS	Test and Evaluation Surveillance and Information System
TIS	Traffic Information Service
TIS-B	Traffic Information Service – Broadcast
TLAT	Technical Link Assessment Team
TLS	Target Level Safety
TMA	Traffic Management Area
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TORCH	Technical ecOnomical and opeRational assessment of an ATM Concept acHeiveable from the year 2005
TQL	Transmit Quality Level
TRACON	Terminal Area CONtrol
TSE	Total System Error
TTF	Traffic To Follow
UAT	Universal Access Transceiver
UHF	Ultra High Frequency: The band of radio frequencies between 300 MHz and 3 GHz, with wavelengths between 1 m and 100 mm.
UMAS	Unmanaged Airspace
UPT	User Preferred Trajectory
USAF	United States Air Force.
UTC	Universal Time, Coordinated, formerly Greenwich Mean Time
Vapp	Final Approach Speed
VDL-4	Very High Frequency Data Link Mode 4
VEPU	Vertical Position Uncertainty
VFOM	Vertical Figure Of Merit
VFR	Visual Flight Rules
VHF	Very High Frequency The band of radio frequencies between 30 MHz and 300 MHz, with wavelengths between 10 m and 1 m.
VMC	Visual Meteorological Conditions

VOR	Very High Frequency Omni-directional Radio
VPL	Vertical Protection Limit
Vref	Reference Landing Velocity
WAAS	Wide Area Augmentation System
WCB	Worst Case Blunder
WG	Working Group
WGS-84	World Geodetic System-1984
xmit	transmit, transmitter

A.2   **Definitions of Terms**

The following are definitions of terms used in this document. Square brackets, e.g., [RTCA DO-242A], refer to entries in the bibliography in Appendix AB.

Airborne Separation Assurance System (ASAS) - An aircraft system based on airborne surveillance that provides assistance to the flight crew supporting the separation of their aircraft from other aircraft.

Airborne Separation Assistance Application - A set of operational procedures for controllers and flight crews that makes use of an Airborne Separation Assurance system to meet a defined operational goal.

Airborne Traffic Situational Awareness applications (ATSA applications) - These applications are aimed at enhancing the flight crews' knowledge of the surrounding traffic situation, both in the air and on the airport surface, and thus improving the flight crew's decision process for the safe and efficient management of their flight. No changes in separation tasks are required for these applications." [PO-ASAS, p.1]

Alert - A general term that applies to all advisories, cautions, and warning information, can include visual, aural, tactile, or other attention-getting methods.

Applications - These are the functions for which the ASA system is to be used (§1.3.7).

Approach Spacing for Instrument Approaches (ASIA) - An application, described in Appendix I, in which, when approaching an airport, the flight crew uses the CDTI display to help them control their Ownship distance behind the preceding aircraft.

ASAS application - A set of operational procedures for controllers and flight crews that makes use of the capabilities of ASAS to meet a clearly defined operational goal. [PO-ASAS, p. 1]

Assured Collision Avoidance Distance (ACAD) - The minimum assured vertical and horizontal distances allowed between aircraft geometric centers. If this distance is violated, a collision or dangerously close spacing will occur. These distances are fixed numbers calculated by risk modeling.

Assured Normal Separation Distance (ANSD) - The normal minimum assured vertical and horizontal distances allowed between aircraft geometric centers. These distances are entered by the pilot or set by the system. Initially the ANSD will be based on current separation standards (and will be larger than the ACAD). In the long term, collision risk modeling will set the ANSD. Ultimately the ANSD may be reduced toward the value of the ACAD.

Automatic Dependent Surveillance-Broadcast (ADS-B) - ADS-B is a function on an aircraft or surface vehicle operating within the surface movement area that periodically broadcasts its state vector (horizontal and vertical position, horizontal

and vertical velocity) and other information. ADS-B is automatic because no external stimulus is required to elicit a transmission; it is dependent because it relies on on-board navigation sources and on-board broadcast transmission systems to provide surveillance information to other users.

Availability - Availability is an indication of the ability of a system or subsystem to provide usable service. Availability is expressed in terms of the probability of the system or subsystem being available at the beginning of an intended operation.

Background Application - An application that applies to all surveilled traffic of operational interest. One or more background applications may be in use in some or all airspace (or on the ground), but without flight crew input or automated input to select specific traffic. Background applications include: Enhanced Visual Acquisition (EVAcq), Conflict Detection (CD), Airborne Conflict Management (ACM), Airport Surface Situational Awareness (ASSA), and Final Approach and Runway Occupancy Awareness (FAROA).

Coast Interval - The elapsed time since a report from any source has been correlated with the track.

Cockpit Display of Traffic Information (CDTI) - The pilot interface portion of a surveillance system. This interface includes the traffic display and all the controls that interact with such a display. The CDTI receives position information of traffic and Ownship from the airborne surveillance and separation assurance processing (ASSAP) function. The ASSAP receives such information from the surveillance sensors and Ownship position sensors.

Collision Avoidance Zone (CAZ) - Zone used by the system to predict a collision or dangerously close spacing. The CAZ is defined by the sum of Assured Collision Avoidance Distance (ACAD) and position uncertainties.

Collision Avoidance Zone (CAZ) Alert - An alert that notifies aircraft crew that a CAZ penetration will occur if immediate action is not taken. Aggressive avoidance action is essential.

Conflict - A predicted violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based. This document only addresses aircraft traffic. See *Traffic Conflict*.

Conflict Detection - The discovery of a conflict as a result of a computation and comparison of the predicted flight paths of two or more aircraft for the purpose of determining conflicts (ICAO).

Conflict Detection Zone (CDZ) Alert - An alert issued at the specified look ahead time prior to CDZ penetration if timely action is not taken. Timely avoidance action is required.

Conflict Detection Zone (CDZ) Penetration Notification - Notification to the crew when the measured separation is less than the specified CDZ.

Conflict Detection Zone (CDZ) - Zone used by the system to detect conflicts. The CDZ is defined by the sum of ANSD, position uncertainties, and trajectory uncertainties. By attempting to maintain a measured separation no smaller than the CDZ, the system assures that the actual separation is no smaller than the ANSD.

Conflict Prevention - The act of informing the flight crew of flight path changes that will create conflicts.

Conflict Resolution - A maneuver that removes all predicted conflicts over a specified "look-ahead" horizon. (ICAO - The determination of alternative flight paths, which would be free from conflicts and the selection of one of these flight paths for use.)

Conformal - A desirable property of map projections. A map projection (a function that associate points on the surface of an ellipsoid or sphere representing the earth to points on a flat surface such as the CDTI display) is said to be *conformal* if the angle between any two curves on the first surface is preserved in magnitude and sense by the angle between the corresponding curves on the other surface.

Correlation - The process of determining that a new measurement belongs to an existing track.

Coupled Application - Coupled applications are those applications that operate only on specifically-chosen (either by the flight crew or automation) traffic. They generally operate only for a specific flight operation. Coupled applications include Enhanced Visual Approach, Approach Spacing for Instrument Approaches, and Independent Closely Spaced Parallel Approaches.

Coupled Target - A coupled target is a target upon which a coupled application is to be conducted.

Covariance - A two dimensional symmetric matrix representing the uncertainty in a track's state. The diagonal entries represent the variance of each state; the off-diagonal terms represent the covariances of the track state.

Data Block - A block of information about a selected target that is displayed somewhere around the edge of the CDTI display, rather than mixed in with the symbols representing traffic targets in the main part of the display.

Data Tag - A block of information about a target that is displayed next to symbol representing that target in the main part of the CDTI display.

Desirable - The capability denoted as *Desirable* is not required to perform the procedure but would increase the utility of the operation.

Display Range - The maximum distance from Ownship that is represented on the *CDTI* display (§3.3.3.1.1.1). If the *CDTI* display is regarded as a map, then longer display ranges correspond to smaller map scales, and short display ranges correspond to larger map scales.

Domain - Divisions in the current airspace structure that tie separation standards to the surveillance and automation capabilities available in the ground infrastructure. Generally there are four domains: surface, terminal, en route, and oceanic/remote and uncontrolled. For example, terminal airspace, in most cases comprises airspace within 30 miles and 10,000 feet AGL of airports with a terminal automation system and radar capability. Terminal IFR separation standards are normally 3 miles horizontally and 1000 feet vertically.

Enhanced Visual Acquisition (EVAcq) - The enhanced visual acquisition application is an enhancement for the out-the-window visual acquisition of aircraft traffic and potentially ground vehicles, (§C.1.1.2 of Appendix C). Pilots will use a *CDTI* to supplement and enhance out-the-window visual acquisition. Pilots will continue to visually scan out of the window while including the *CDTI* in their instrument scan, (§C.1.2.1 of Appendix C),***Note:** An extended display range capability of at least 90 NM from Ownship is desirable for the ACM application*

Estimation - The process of determining a track's state based on new measurement information

Explicit Coordination - Explicit coordination of resolutions requires that the aircraft involved in a conflict communicate their intentions to each other and (in some strategies) authorize/confirm each other's maneuvers. One example of an explicit coordination technique would be the assignment of a 'master' aircraft, which determines resolutions for other aircraft involved in the conflict. Another is the crosslink used in *ACAS*.

Extended Display Range - Extended display range is the capability of the CDTI to depict traffic at ranges beyond the standard display range maximum of 40 NM.

Note: An extended display range capability of at least 90 NM from Ownship is desirable for the ACM application. (§3.3.3.1.1.3)

Extended Runway Center Line - An extension outwards of the center line of a runway, from one or both ends of that runway.

Extrapolation - The process of predicting a track's state forward in time based on the track's last kinematic state.

Field of View - The *field of view* of a *CDTI* is the geographical region within which the *CDTI* shows *traffic targets*. (Some other documents call this the field of regard.)

Flight Crew - One or more cockpit crew members required for the operation of the aircraft.

Generic Conflict - A violation of parameterized minimum separation criteria for adverse weather, aircraft traffic, special use airspace, other airspace, turbulence, noise sensitive areas, terrain and obstacles, etc. There can be different levels or types of conflict based on how the parameters are defined. Criteria can be either geometry based or time-based.

GNSS Sensor Integrity Risk - The probability of an undetected failure that results in NSE (navigation system error) that significantly jeopardizes the total system error (TSE) exceeding the containment limit. [DO-247, §5.2.2.1]

Ground Speed - The magnitude of the horizontal velocity vector (see *velocity*). In these MASPS it is always expressed relative to a frame of reference that is fixed with respect to the earth's surface such as the WGS-84 ellipsoid.

Ground Track Angle - The direction of the horizontal velocity vector (see *velocity*) relative to the ground as noted in Ground Speed.

Hazard Classification - An index into the following table:

Hazard Class	Acceptable failure rate
1 "Catastrophic" consequences	10^{-9} per flight hour
2 "Hazardous/Severe Major" consequences	10^{-7} per flight hour
3 "Major" consequences	10^{-5} per flight hour
4 "Minor" consequences	10^{-3} per flight hour
5 Inconsequential no effect	

Horizontal Velocity - The horizontal component of velocity relative to a ground reference (see *Velocity)*.

Height Above Ellipsoid - Height above the WGS-84 reference ellipsoid.

Implicit Coordination - Implicitly coordinated resolutions are assured not to conflict with each other because the responses of each pilot are restricted by common rules. A terrestrial example of an implicit coordination rule is "yield to the vehicle on of conflict based on how the parameters are defined." Criteria can be either geometry based or time-based.

Integrity Containment Risk (ICR) - The per-flight-hour probability that a parameter will exceed its containment bound without being detected and reported within the required time to alert. (See also *Integrity* and *Surveillance Integrity Level*.)

International Civil Aviation Organization (ICAO) - A United Nations organization that is responsible for developing international standards, recommended practices, and procedures covering a variety of technical fields of aviation.

Latency - Latency is the time incurred between two particular interfaces. Total latency is the delay between the true time of applicability of a measurement and the time that the measurement is reported at a particular interface (the latter minus the former). Components of the total latency are elements of the total latency allocated between different interfaces. Each latency component will be specified by naming the interfaces between which it applies.

Low Level Alert - An optional alert issued when CDZ penetration is predicted outside of the CDZ alert boundary.

Mixed Equipage - An environment where all aircraft do not have the same set of avionics. For example, some aircraft may transmit ADS-B and others may not, which could have implications for ATC and pilots. A mixed equipage environment will exist until all aircraft operating in a system have the same set of avionics.

Nautical Mile (NM) - A unit of length used in the fields of air and marine navigation. In this document, a nautical mile is always the international nautical mile of 1852 m exactly.

Navigation Accuracy Category Position (NACP) - The NACP parameter describes the accuracy region about the reported position within which the true position of the surveillance position reference point is assured to lie with a 95% probability at the reported time of applicability.

Navigation Accuracy Category Velocity (NACV) - The NACV parameter describes the accuracy about the reported velocity vector within which the true velocity vector is assured to be with a 95% probability at the reported time of applicability.

Navigation Integrity Category (NIC) - The NIC parameter describes an integrity containment region about the reported position, within which the true position of the surveillance position reference point is assured to lie at the reported time of applicability.

Navigation Sensor Availability - An indication of the ability of the guidance function to provide usable service within the specified coverage area, and is defined as the portion of time during which the sensor information is to be used for navigation, during which reliable navigation information is presented to the crew, autopilot, or other system managing the movement of the aircraft. Navigation sensor availability is specified in terms of the probability of the sensor information being available at the beginning of the intended operation. [RTCA DO-247, §5.2.2.3]

Navigation Sensor Continuity - The capability of the sensor (comprising all elements generating the signal in space and airborne reception) to perform the guidance

function without non-scheduled interruption during the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation Sensor Continuity Risk - The probability that the sensor information will be interrupted and not provide navigation information over the period of the intended operation. [RTCA DO-247, §5.2.2.2]

Navigation System Integrity - This relates to the trust that can be placed in the correctness of the navigation information supplied. Integrity includes the ability to provide timely and valid warnings to the user when the navigation system must not be used for navigation.

Ownship - From the perspective of a flight crew, or of the ASSAP and CDTI functions used by that flight crew, the Ownship is the ASA participant (aircraft or vehicle) that carries that flight crew and those ASSAP and CDTI functions.

Persistent Error - A persistent error is an error that occurs regularly. Such an error may be the absence of data or the presentation of data that is false or misleading. An unknown measurement bias may, for example, cause a persistent error.

Positional Uncertainty - Positional uncertainty is a measure of the potential inaccuracy of an aircraft's position-fixing system and, therefore, of ADS-B-based surveillance. Use of the Global Positioning System (GPS) reduces positional inaccuracy to small values, especially when the system is augmented by either space-based or ground-based subsystems. However, use of GPS as the position fixing system for ADS-B cannot be assured, and positional accuracy variations must be take into account in the calculation of CDZ and CAZ. When aircraft are in close proximity and are using the same position-fixing system, they may be experiencing similar degrees of uncertainty. In such a case, accuracy of relative positioning between the two aircraft may be considerably better than the absolute positional accuracy of either. If, in the future, the accuracy of relative positioning can be assured to the required level, it may be possible to take credit for the phenomenon in calculation of separation minima. For example, vertical separation uses this principle by using a common barometric altitude datum that is highly accurate only in relative terms.

Primary Surveillance Radar (PSR) - A radar sensor that listens to the echoes of pulses that it transmits to illuminate aircraft targets. PSR sensors, in contrast to secondary surveillance radar (SSR) sensors, do not depend on the carriage of transponders on board the aircraft targets.

Proximity Alert - An alert to the flight crew that something is within pre-determined proximity limits (e.g., relative range, or relative altitude difference) of own vehicle.

Range Reference - The CDTI feature of displaying range rings or other range markings at specified radii from the Ownship symbol.

Regime - Divisions in the future airspace structure in contrast to the current concept of domains. Based on the European concept, the three regimes are:

1. **Managed Airspace (MAS)**

   - Known traffic environment

   - Route network 2D/3D and free routing

   - Separation responsibility on the ground, but may be delegated to the pilots in defined circumstances

2. **Free Flight Airspace (FFAS) – FFAS is also known as Autonomous Airspace.**

   - Known traffic environment

3. **Autonomous operations Separation responsibility in the air Unmanaged Airspace (UMAS)**

   - Unknown traffic environment

   - See [Rules of the air] See section H.1.1.3.

Registration - The process of aligning measurements from different sensors by removing systematic biases.

Required - The capability denoted as Required is necessary to perform the desired application.

Safe Flight 21 - The Safe Flight 21 Program is a joint government/industry initiative designed to demonstrate and validate, in a real-world environment, the capabilities of advanced surveillance systems and air traffic procedures. The program is demonstrating nine operational enhancements selected by RTCA, and providing the FAA and industry with valuable information needed to make decisions about implementing applications that have potential for significant safety, efficiency, and capacity benefits.

Secondary Surveillance Radar (SSR) - A radar sensor that listens to replies sent by transponders carried on board airborne targets. SSR sensors, in contrast to *primary surveillance radar* (PSR*)* sensors, require the aircraft under surveillance to carry a *transponder*.

Selected Target - A selected target is a target for which additional information is requested by the flight crew.

Sensor - A measurement device. An air data sensor measures atmospheric pressure and temperature, to estimate pressure altitude, and pressure altitude rate, airspeed, etc. A *primary surveillance radar* (PSR) sensor measures its antenna direction and the times of returns of echoes of pulses that it transmits to determine the ranges and

bearings of airborne targets. A *secondary surveillance radar* (SSR) sensor measures its antenna direction and the times of returns of replies from airborne transponders to estimate the ranges and bearings of airborne targets carrying those transponders.

Separation - Requirements or Separation Standards The minimum distance between aircraft/vehicles allowed by regulations. Spacing requirements vary by various factors, such as radar coverage (none, single, composite), flight regime (terminal, en route, oceanic), and flight rules (instrument or visual).

Separation Violation - Violation of appropriate separation requirements.

Source Track - A track that is composed of measurements and state information that are derived from a single surveillance source.

Spacing - A distance maintained from another aircraft for specific operations.

Subsystem Availability Risk - The probability, per flight hour, that an ASA subsystem is not available, that is, that it is not meeting its functional and performance requirements. (§3.3.1.2)

Surveillance Integrity Level (SIL) - The Surveillance Integrity Level (SIL) defines the probability of the integrity containment region that is indicated by the NIC parameter being exceeded, without alerting, including the effects of the airborne equipment condition.

State (vector) - An aircraft's current horizontal position, vertical position, horizontal velocity, vertical velocity, turn indication, and navigational accuracy and integrity.

Target Selection - Manual process of flight crew selecting a target.

Target - Traffic of particular interest to the flight crew.

TCAS Potential Threat - A traffic target, detected by TCAS equipment on board theOwnship, that has passed the Potential Threat classification criteria for a TCAS TA (traffic advisory) and does not meet the Threat Classification criteria for a TCAS RA (resolution advisory). ([DO-185A, §1.8)

(If the ASAS Ownship CDTI display is also used as a TCAS TA display, then information about TCAS potential threats will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS Proximate Traffic - A traffic target, detected by TCAS equipment on board theOwnship, that is within 1200 feet and 6 NM of theOwnship. ([DO-185A]. §1.8) (If the ASAS Ownship CDTI display is also used as a TCAS TA display, then information about TCAS proximate traffic targets will be conveyed to the CDTI, possibly via the ASSAP function.)

TCAS-Only Target - A traffic target about which TCAS has provided surveillance information, but which the ASSAP function has not correlated with targets from other surveillance sources (such as ADS-B, TIS, or TIS-B).

Time of Applicability - The time that a particular measurement or parameter is (or was) relevant.

Track - (1) A sequence of reports from the ASSAP function that all pertain to the same *traffic target*. (2) Within the ASSAP function, a sequence of estimates of traffic target state that all pertain to the same traffic target.

Track Angle - See *ground track angle*.

Track State - The basic kinematic variables that define the state of the aircraft or vehicle of a track, e.g., position, velocity, acceleration.

Traffic Conflict - Predicted converging of aircraft in space and time, which constitutes a violation of a given set of separation minima. (ICAO)

Traffic - All aircraft/vehicles that are within the operational vicinity ofOwnship.

Traffic Information Service – Broadcast - A surveillance service that broadcasts traffic information derived from one or more ground surveillance sources to suitably equipped aircraft or surface vehicles, with the intention of supporting ASA applications.

Traffic Symbol - A depiction on the CDTI display of an aircraft or vehicle other than the *Ownship* (§3.3.3.1.2.2).

Traffic Target - This is an aircraft or vehicle under surveillance. In the context of the ASA subsystems at a receiving ASA participant, traffic targets are aircraft or vehicles about which information is being provided (by ADS-B, TIS-B, TCAS, etc.) to the ASSAP

Transponder - A piece of equipment carried on board an aircraft to support the surveillance of that aircraft by *secondary surveillance radar* sensors. A transponder receives on the 1030 MHz and replies on the 1090 MHz downlink frequency.

Trajectory Uncertainty - Trajectory uncertainty is a measure of predictability of the future trajectory of each aircraft. There are a number of factors involved in trajectory predictability. These include knowledge of a valid future trajectory, capability of the aircraft to adhere to that trajectory, system availability (e.g., ability to maintain its intended trajectory with a system failure in a non redundant system versus a triple redundant system), and others.

Uncompensated Latency - Uncompensated latency in the delivery of own-ship position measurements to ASSAP is latency (q.v.) that could be compensated as described in DO-302 but is not compensated.

User-Preferred Trajectories (UPT) - A series of one or more waypoints that the crew has determined to best satisfy their requirements.

Velocity - The rate of change of position. Horizontal velocity is the horizontal component of velocity and vertical velocity is the vertical component of velocity. In these MASPS, velocity is always expressed relative to a frame of reference, such as the WGS-84 ellipsoid

Vref - The reference landing air speed for an aircraft. It is weight dependent. Flight crews may vary their actual landing speed based on winds, etc.

A recommendation and a question for possible discussion with the WG:

[ ] Remove the definition, above, of "Uncompensated latency;" delete assumption 1.5.1. Own-ship Position; and change "uncompensated latency" to "residual latency" in 2.2.4.1. General Requirements (Randy's section).

[ ] Should we change figure 1-1, "Overview of ASA Architecture," to be consistent figure 1-1 of DO-302, viz., to show a Surveillance Transmit Processing function block between own-ship sensors and ASSAP?

APPENDIX B

BIBLIOGRAPHY

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B.1

APPENDIX C

**EXAMPLE FUNCTIONAL ARCHITECTURE FOR
AIRBORNE SURVEILLANCE AND SEPARATION ASSURANCE
PROCESSING (ASSAP)**

**APPENDIX C EXAMPLE FUNCTIONAL ARCHITECTURE FOR AIRBORNE
SURVEILLANCE AND SEPARATION ASSURANCE PROCESSING (ASSAP)**

C.1   Introduction

This appendix outlines an example functional architecture for the ASSAP component of
the Airborne Separation Assurance System (ASAS). The ASSAP subsystem performs the
surveillance and application-specific processing functions of ASAS. The architecture
presented in this appendix meets or exceeds the requirements listed in this document.
Additionally, this architecture has been tested and validated with real-world and
simulated data sets, including:

a. Operational 1090ES ADS-B, TIS-B, and TCAS data obtained from flight tests
performed at the William J. Hughes [FAA] Technical Center in July 2007.

b. Simulated surveillance data based on RNAV approaches to Hartsfield-Jackson
Atlanta International Airport in August 2006 (listed in sections TBD).

C.2   Assumptions

The functional architecture presented in this appendix is based on the following
assumptions:

a. ASSAP will receive inputs from a single-link receiver (i.e., ADS-B and ADS-R are
received on the same frequency).

b. Mode S addresses for TCAS targets are available to ASSAP via the TCAS data bus.
For the cases in which this assumption is not true, a workaround is presented in
section TBD.

C.3   Surveillance Processing

The ASSAP Surveillance Processor is required to establish tracks from ADS-B and TIS-
B traffic reports, cross-reference traffic from different surveillance sources (ADS-B, TIS-
B, TCAS), estimate track state (i.e., position, velocity) and track quality, and delete tracks
when data age exceeds a maximum allowable coast time (dictated by applications). The
Surveillance Processing function has been decomposed into the following subfunctions:

a. Track Generation and Maintenance

b. Inter-Source Correlation

c. Best Source Selection

d. Track Termination

e. Common Time Track Extrapolation

Figure C-1 contains a block diagram depicting the Surveillance Processing function.
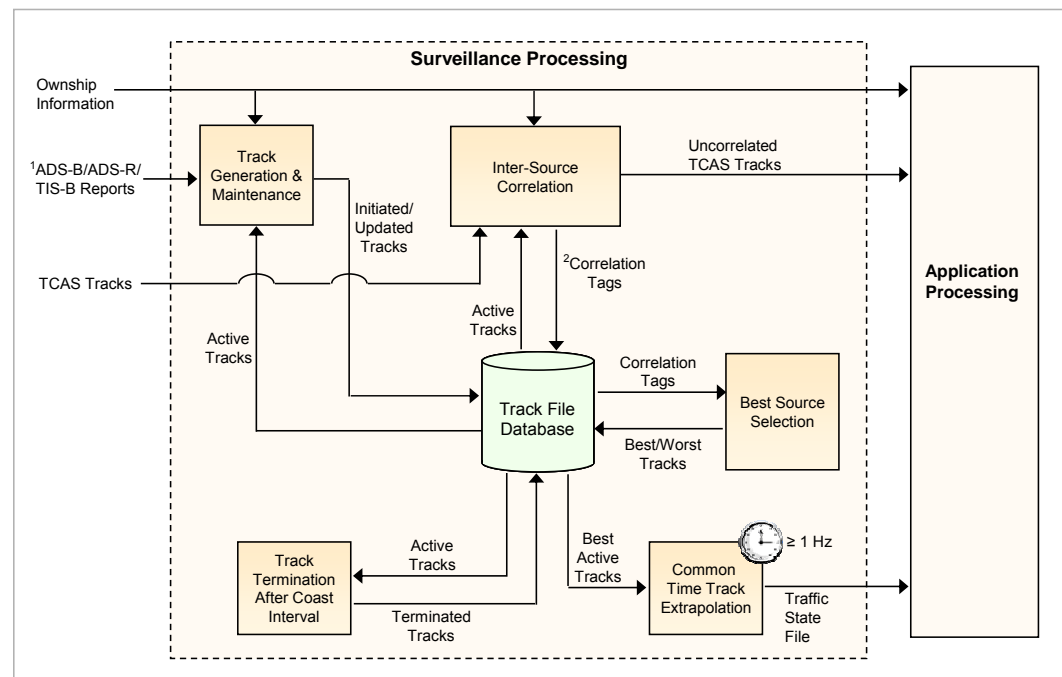

Figure C-1 Block diagram of the Surveillance Processing function.

Note:

1. *Depending on the implementation (UAT or 1090ES), ASSAP will receive "full" reports (full state vector and state uncertainty) or "partial" reports (state vector and state uncertainty separately).*

2. *Correlation tags include TCAS correlation tags and track-to-track (i.e., ADS-B to TIS-B) correlation tags.*

C.3.1   Track Generation and Maintenance

The Track Generation and Maintenance function is responsible for track initiation and subsequent updates. This function is an adaptation of a source-level tracker; ADS-B, ADS-R, and TIS-B tracks are established separately (and categorized by type). An effort was made to define this function in a manner applicable to both UAT and 1090ES implementations. However, UAT and 1090ES reports are inherently different, thus inputs to ASSAP are inherently different (depending on the implementation). Additionally, 1090ES characteristics and strict adherence to receiver standards (DO-260A) further [1]complicate inputs to ASSAP. As a result, the architecture in this appendix contains implementation-specific tracking functions.

Note: Although 1090ES receivers generate "state vector" reports (event-driven by the reception of a position or velocity message), position and velocity in any given

report correspond to different times of applicability. Additionally, DO-260A standards allow a receiver to repeat a previous position if a new position message is not received, as long as the position time of applicability is encoded (and likewise for velocity). As observed during 1090ES flight tests at the FAA Technical Center, receivers will produce partially valid state vectors (i.e., valid velocity with invalid/repeated position).

C.3.1.1   Track Generation and Maintenance (1090ES Implementation)

Figure C-2 contains a block diagram depicting the Track Generation and Maintenance function for the 1090ES implementation of ASSAP.
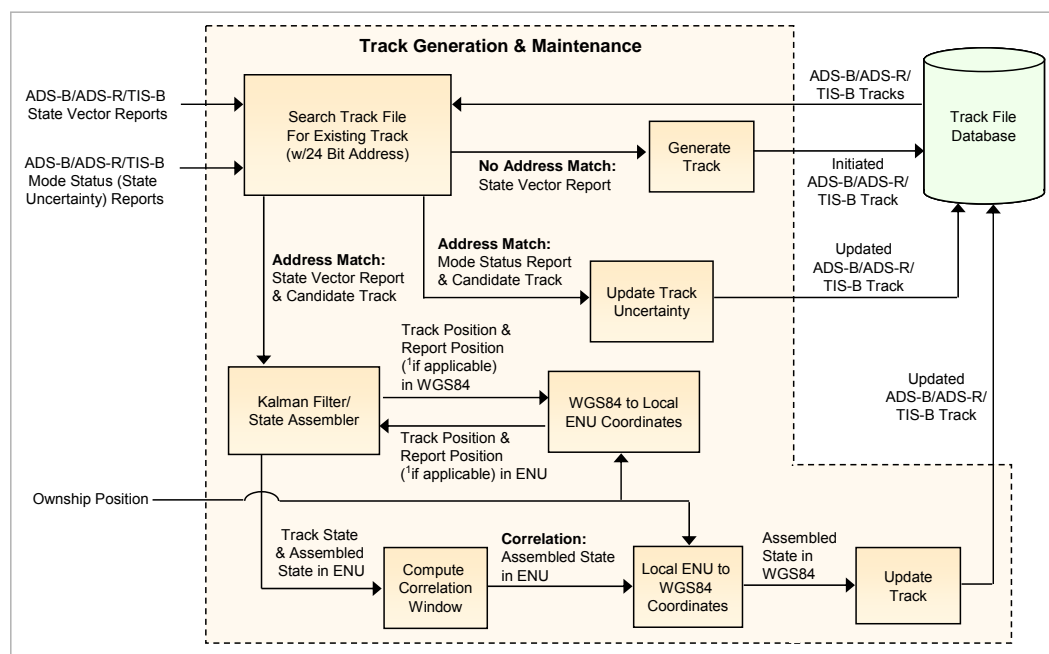
Figure C-2 Block Diagram of the Track Generation and Maintenance Function for 1090ES Implementations of ASSAP

Note: Reported position is applicable only if a position message was received, if a velocity message was received, velocity is used by the state assembler.

C.3.1.1.1   Track Generation (1090ES Implementation)

Upon reception of a state vector report, ASSAP searches for a track of the same type (ADS-B, ADS-R, TIS-B) and with the same 24-bit address as the report. If no match is found, ASSAP generates a new track containing the following parameters:

a.   System time (track time of applicability)

b.   Track type (ADS-B, ADS-R, TIS-B)

    c.   24-bit address

    d.   [1]Position (latitude, longitude, altitude)

    e.   [1]Velocity (East/West velocity, North/South velocity, altitude rate)

    f.   NIC

    g.   [2]NACp = 5

    h.   [2]NACv = 1

    i.   [2]SIL = 0

    j.   [3]State covariance matrices

Note:

1. *Different times of applicability for position and velocity are disregarded during track initialization.*

2. *Track quality parameters are initially set to the minimum values allowed by the Enhanced Visual Acquisition application (with the exception that NACv is set to 1 in order to make the velocity uncertainty a known value). The contents of Mode Status reports will overwrite this data.*

3. *State covariance matrices are derived from NACp and NACv values stored in the track and pertain to x/y/z dimensions in the local East/North/Up (ENU) coordinate frame:*

Initial covariance matrix for the x-dimension

$$\begin{pmatrix} \sigma_x^2 & \sigma_{x\dot{x}} \\ \sigma_{x\dot{x}} & \sigma_{\dot{x}}^2 \end{pmatrix} = \begin{pmatrix} \sigma_{epu}^2 & \sigma_{epu}\sigma_{hva} \\ \sigma_{epu}\sigma_{hva} & \sigma_{hva}^2 \end{pmatrix}$$

where

σ_{epu} *(standard deviation of estimated position uncertainty) is derived from NACp.*

σ_{hva} *(standard deviation of horizontal velocity accuracy)is derived from NACv.*

Initial covariance matrix for the y-dimension

$$
\begin{pmatrix} \sigma_y^2 & \sigma_{y\dot{y}} \\ \sigma_{y\dot{y}} & \sigma_{\dot{y}}^2 \end{pmatrix} = \begin{pmatrix} \sigma_{epu}^2 & \sigma_{epu}\sigma_{hva} \\ \sigma_{epu}\sigma_{hva} & \sigma_{hva}^2 \end{pmatrix}
$$

Initial covariance matrix for the z-dimension

$$
\begin{pmatrix} \sigma_z^2 & \sigma_{z\dot{z}} \\ \sigma_{z\dot{z}} & \sigma_{\dot{z}}^2 \end{pmatrix} = \begin{pmatrix} \sigma_{vepu}^2 & \sigma_{vepu}\sigma_{vva} \\ \sigma_{vepu}\sigma_{vva} & \sigma_{vva}^2 \end{pmatrix}
$$

where

σ_{vepu} *(standard deviation of vertical estimated position uncertainty) is derived from NACp if geometric altitude is used and NACp ≥ 9, or an assumed value otherwise.*

σ_{vva} *(standard deviation of vertical velocity accuracy)is derived from NACv if geometric altitude is used, or an assumed value otherwise.*

C.3.1.1.2   Track Maintenance (1090ES Implementation)

Upon reception of a mode status report, ASSAP searches for a track of the same type (ADS-B, ADS-R, TIS-B) and with the same 24-bit address as the report. If a match is found, NACp, NACv, and SIL values in the track are updated with the values in the report.

Upon reception of a state vector update, ASSAP searches for a track of the same type (ADS-B, ADS-R, TIS-B) and with the same 24-bit address as the report. If a match is found, the reported state component (position or velocity) with the lowest data age (determined with respective times of applicability) is sent to the state assembler function along with candidate track information.

C.3.1.1.2.1   State Assembler

The state assembly function uses three independent, two state Kalman filters. The filter state consists of position and velocity. The state is tracked in each of three orthogonal Cartesian dimensions (local ENU). The filter takes as input the measured position or velocity, the candidate track state, and the candidate track state covariance. The filter also requires as input the time of the measurement. The filter produces an "assembled" state vector and covariance. Regardless of update type (position or velocity), the state assembler temporarily (i.e., in memory) converts track position from WGS84 to local ENU coordinates:

Track and ownship positions are first converted from WGS84 to ECEF coordinates:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \left(\dfrac{a}{\chi}+h\right)\cos\phi\cos\lambda \\ \left(\dfrac{a}{\chi}+h\right)\cos\phi\sin\lambda \\ \left(\dfrac{a(1-e^2)}{\chi}+h\right)\sin\phi \end{bmatrix} \tag{1}$$

where

$a = semi\text{-}major\ axis\ =\ 6378137.0\ meters$

$e^2 = first\ eccentricity\ squared\ =\ 6.69437999014\ x\ 10^{-3}$

$\phi = latitude$

$\lambda = longitude$

$h = altitude$

$\chi = \sqrt{1 - e^2 \sin^2\phi}$

Track ENU position is derived from track and ownship ECEF positions:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\phi'\cos\lambda & -\sin\phi'\sin\lambda & \cos\phi' \\ \cos\phi'\cos\lambda & \cos\phi'\sin\lambda & \sin\phi' \end{bmatrix} \begin{bmatrix} X_t - X_o \\ Y_t - Y_o \\ Z_t - Z_o \end{bmatrix} \tag{2}$$

where

$\phi' = tan^{-1}\left(\dfrac{Z_o}{\sqrt{X_o^2 + Y_o^2}}\right) =$ *geocentric latitude of ownship*

$(X_o, Y_o, Z_o) =$ *ECEF position of ownship*

$(X_t, Y_t, Z_t) =$ *ECEF position of target*

Track state (in local ENU) is then extrapolated to the time of applicability of the state vector report:

$$\hat{x} = x + \dot{x}(dt)$$

$$\hat{y} = y + \dot{y}(dt)$$

$$\hat{z} = z + \dot{z}(dt)$$

$$\hat{\dot{x}} = \dot{x}$$

$$\hat{\dot{y}} = \dot{y}$$

$$\hat{\dot{z}} = \dot{z} \tag{3}$$

where

(x, y, z) *is track position in local ENU coordinates.*

$(\dot{x}, \dot{y}, \dot{z})$ *is track velocity (East/West, North/South, Altitude velocity components).*

$(\hat{x}, \hat{y}, \hat{z})$ *is predicted track position in local ENU coordinates.*

$(\hat{\dot{x}}, \hat{\dot{y}}, \hat{\dot{z}})$ *is predicted track velocity.*

dt is the time difference between the current report and the last track update.

The next step in the filtering process is the extrapolation of track covariance matrices (note that only formulas for the x/east dimension are shown, as they are identical for all dimensions):

$$\sigma_{\hat{x}}^2 = \sigma_x^2 + (dt)^2 \sigma_{\dot{x}}^2 + 2dt\sigma_{x\dot{x}} + \frac{Q(dt)^4}{4}$$

$$\sigma_{\hat{\dot{x}}}^2 = \sigma_{\dot{x}}^2 + (dt)^2 Q \tag{4}$$

$$\sigma_{\hat{x}\hat{\dot{x}}} = \sigma_{x\dot{x}} + (dt)\sigma_{\dot{x}}^2 + \frac{(dt)^3 Q}{2}$$

where

Q is the process (plant) noise variance. Typical values are on the order of 0.0025g2 (with g = 9.8 m/s2). However, extensive simulation testing has shown that Q = 0.0625g2 is optimal for maneuvering aircraft.

C.3.1.1.2.1.1   State Assembly With Position Updates

Equations (1) and (2) are used to convert a position update from WGS84 to local ENU coordinates. Measurement position variances are derived from the NACp value stored in the candidate track. It is important to note that this is the technique used to link state vector and mode status reports. It is possible that a mode status report updated NACp and NACv in the track milliseconds before the arrival of the state vector update. First, the residual (or innovation) variances are calculated with extrapolated track position variances and estimated measurement position variances (based on most current NACp):

$$\sigma^2_{v_x} = \sigma^2_{\hat{x}} + \sigma^2_{epu}$$

$$\sigma^2_{v_y} = \sigma^2_{\hat{y}} + \sigma^2_{epu}$$

$$\sigma^2_{v_z} = \sigma^2_{\hat{z}} + \sigma^2_{vepu} \tag{5}$$

where

$\left(\sigma^2_{\hat{x}}, \sigma^2_{\hat{y}}, \sigma^2_{\hat{z}} \right)$ *are extrapolated track position variances*

$\left(\sigma^2_{epu}, \sigma^2_{vepu} \right)$ *are estimated measurement position variances derived from NACp*

Gain vectors are then calculated with extrapolated track and residual variances:

$$w_{0_x} = \frac{\sigma^2_{\hat{x}}}{\sigma^2_{v_x}} \, , \, w_{1_x} = \frac{\sigma_{\hat{x}\hat{x}}}{\sigma^2_{v_x}}$$

$$w_{0_y} = \frac{\sigma^2_{\hat{y}}}{\sigma^2_{v_y}} \, , \, w_{1_y} = \frac{\sigma_{\hat{y}\hat{y}}}{\sigma^2_{v_y}}$$

$$w_{0_z} = \frac{\sigma^2_{\hat{z}}}{\sigma^2_{v_z}} \, , \, w_{1_z} = \frac{\sigma_{\hat{z}\hat{z}}}{\sigma^2_{v_z}} \tag{6}$$

The assembled state is generated as follows:

$$x_a = \hat{x} + w_{0_x}(x_m - \hat{x})$$

$$y_a = \hat{y} + w_{0_y}(y_m - \hat{y})$$

$$z_a = \hat{z} + w_{0_z}(z_m - \hat{z})$$

$$\dot{x}_a = \hat{\dot{x}} + w_{1_x}(x_m - \hat{x})$$

$$\dot{y}_a = \hat{\dot{y}} + w_{1_y}(y_m - \hat{y})$$

$$\dot{z}_a = \hat{\dot{z}} + w_{1_z}(z_m - \hat{z})$$

(7)

where

$$\left(x_m, y_m, z_m\right) \text{ are measurement positions in local ENU}$$

The assembled state covariance matrices are calculated as follows:

$$\sigma_{x_a}^2 = (1 - w_{0_x})\sigma_{\hat{x}}^2$$

$$\sigma_{x\dot{x}a} = (1 - w_{0_x})\sigma_{\hat{x}\hat{\dot{x}}}$$

$$\sigma_{\dot{x}_a}^2 = \sigma_{\hat{\dot{x}}}^2 - w_{1_x}\sigma_{\hat{x}\hat{\dot{x}}}$$

$$\sigma_{y_a}^2 = (1 - w_{0_y})\sigma_{\hat{y}}^2$$

$$\sigma_{y\dot{y}a} = (1 - w_{0_y})\sigma_{\hat{y}\hat{\dot{y}}}$$

(8)

$$\sigma_{\dot{y}_a}^2 = \sigma_{\hat{\dot{y}}}^2 - w_{1_y}\sigma_{\hat{y}\hat{\dot{y}}}$$

$$\sigma_{z_a}^2 = (1 - w_{0_z})\sigma_{\hat{z}}^2$$

$$\sigma_{z\dot{z}a} = (1 - w_{0_z})\sigma_{\hat{z}\hat{\dot{z}}}$$

$$\sigma_{\dot{z}_a}^2 = \sigma_{\hat{\dot{z}}}^2 - w_{1_z}\sigma_{\hat{z}\hat{\dot{z}}}$$

The assembled state and track state (both in local ENU coordinates) are then sent to the correlation window function.

C.3.1.1.2.1.2 State Assembly With Velocity Updates

In the case of a velocity update, the residual (or innovation) variances are calculated with extrapolated track velocity variances and estimated measurement velocity variances (based on most current NACv):

$$\sigma_{v_x}^2 = \sigma_{\hat{\dot{x}}}^2 + \sigma_{hva}^2$$

$$\sigma_{v_y}^2 = \sigma_{\hat{\dot{y}}}^2 + \sigma_{hva}^2 \tag{9}$$

$$\sigma_{v_z}^2 = \sigma_{\hat{\dot{z}}}^2 + \sigma_{vva}^2$$

where

$\left(\sigma_{\hat{\dot{x}}}^2, \sigma_{\hat{\dot{y}}}^2, \sigma_{\hat{\dot{z}}}^2 \right)$ *are extrapolated track velocity variances*

$\left(\sigma_{hva}^2, \sigma_{vva}^2 \right)$ *are estimated measurement velocity variances derived from NACv*

Gain vectors are then calculated with extrapolated track and residual variances:

$$w_{0_x} = \frac{\sigma_{\hat{x}\hat{\dot{x}}}}{\sigma_{v_x}^2} , \; w_{1_x} = \frac{\sigma_{\hat{\dot{x}}}^2}{\sigma_{v_x}^2}$$

$$w_{0_y} = \frac{\sigma_{\hat{y}\hat{\dot{y}}}}{\sigma_{v_y}^2} , \; w_{1_y} = \frac{\sigma_{\hat{\dot{y}}}^2}{\sigma_{v_y}^2} \tag{10}$$

$$w_{0_z} = \frac{\sigma_{\hat{z}\hat{\dot{z}}}}{\sigma_{v_z}^2} , \; w_{1_z} = \frac{\sigma_{\hat{\dot{z}}}^2}{\sigma_{v_z}^2}$$

The assembled state is generated as follows:

$$x_a = \hat{x} + w_{0_x} (\dot{x}_m - \hat{\dot{x}})$$

$$y_a = \hat{y} + w_{0_y} (\dot{y}_m - \hat{\dot{y}})$$

$$z_a = \hat{z} + w_{0_z} (\dot{z}_m - \hat{\dot{z}}) \tag{11}$$

$$\dot{x}_a = \hat{\dot{x}} + w_{1_x}(\dot{x}_m - \hat{\dot{x}})$$

$$\dot{y}_a = \hat{\dot{y}} + w_{1_y}(\dot{y}_m - \hat{\dot{y}})$$

$$\dot{z}_a = \hat{\dot{z}} + w_{1_z}(\dot{z}_m - \hat{\dot{z}})$$

where

$$\left(\dot{x}_m, \dot{y}_m, \dot{z}_m\right)$$ are measurement East/West, North/South, and altitude velocities (respectively)

Next, the assembled state covariance matrices are calculated as follows:

$$\sigma_{x_a}^2 = \sigma_{\hat{x}}^2 - w_{0_x}\sigma_{\hat{x}\hat{\dot{x}}}$$

$$\sigma_{x\dot{x}_a} = (1 - w_{1_x})\sigma_{\hat{x}\hat{\dot{x}}}$$

$$\sigma_{\dot{x}_a}^2 = (1 - w_{1_x})\sigma_{\hat{\dot{x}}}^2$$

$$\sigma_{y_a}^2 = \sigma_{\hat{y}}^2 - w_{0_y}\sigma_{\hat{y}\hat{\dot{y}}}$$

$$\sigma_{y\dot{y}_a} = (1 - w_{1_y})\sigma_{\hat{y}\hat{\dot{y}}} \tag{12}$$

$$\sigma_{\dot{y}_a}^2 = (1 - w_{1_y})\sigma_{\hat{\dot{y}}}^2$$

$$\sigma_{z_a}^2 = \sigma_{\hat{z}}^2 - w_{0_z}\sigma_{\hat{z}\hat{\dot{z}}}$$

$$\sigma_{z\dot{z}_a} = (1 - w_{1_z})\sigma_{\hat{z}\hat{\dot{z}}}$$

$$\sigma_{\dot{z}_a}^2 = (1 - w_{1_z})\sigma_{\hat{\dot{z}}}^2$$

The assembled state and track state (both in local ENU coordinates) are then sent to the correlation window function.

C.3.1.1.2.2 Correlation Window

The correlation window is used to perform a final check that ensures the received state vector report truly corresponds to the candidate track. The correlation window is an

estimated maximum distance between two reported positions, based on the concepts shown in Figure C-3.
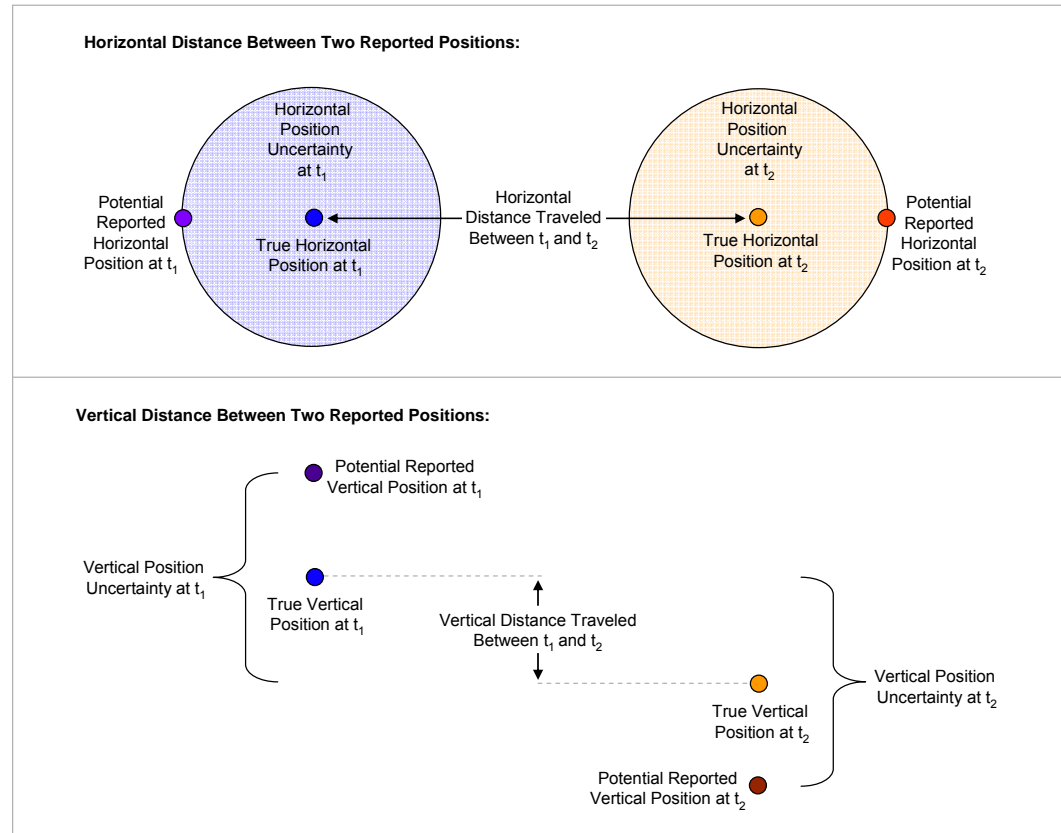
Figure C-3 Estimated Maximum Horizontal and Vertical Distances Between Two Reported Positions

The correlation window is calculated as follows:

$$r_h = \sqrt{\dot{x}_a^2 + \dot{y}_a^2}\,(dt) + 2(3\sigma'_{epu})$$

$$r_v = |\dot{z}_a|\,dt + 2(3\sigma'_{vepu}) \tag{13}$$

where

σ'_{epu}, σ'_{vepu} are derived from degraded track NACp (NACp -1)

r_h is estimated maximum horizontal distance between the assembled and track positions

r_v is estimated maximum vertical distance between the assembled and track positions

Note: That these estimates assume linear dynamics (no acceleration)

Next, differences between assembled and track positions are calculated:

$$d_h = \sqrt{(x_a - x)^2 + (y_a - y)^2}$$
$$d_v = |z_a - z| \tag{14}$$

where

d_h *is the difference between assembled/filtered and track horizontal positions.*

d_v *is the difference between assembled/filtered and track vertical positions.*

If $d_h \le r_h$ *and* $d_v \le r_v$, *spatial correlation occurs.*

C.3.1.1.2.3   Track Updates

Upon successful correlation of assembled and track states, the assembled state is converted from local ENU to WGS84 coordinates:

Ownship position is first converted from WGS84 to ECEF coordinates using equation (1). The assembled/filtered target position is then converted from ENU to ECEF coordinates:

$$\begin{bmatrix} X_a \\ Y_a \\ Z_a \end{bmatrix} = \begin{bmatrix} -\sin\lambda & -\sin\phi'\cos\lambda & \cos\phi'\cos\lambda \\ \cos\lambda & -\sin\phi'\sin\lambda & \cos\phi'\sin\lambda \\ 0 & \cos\phi' & \sin\phi' \end{bmatrix} \begin{bmatrix} x_a \\ y_a \\ z_a \end{bmatrix} + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} \tag{15}$$

where

$\phi' = \tan^{-1}\left(\dfrac{Z_o}{\sqrt{X_o^2 + Y_o^2}}\right) =$ *geocentric latitude of ownship*

$(X_o, Y_o, Z_o) =$ *ECEF position of ownship*

$\lambda =$ *ownship longitude*

Assembled/filtered target position in ECEF is then converted to WGS84 coordinates through a 15 step process:

$$r_{ecef} = \sqrt{X_a^2 + Y_a^2}$$

$$E^2 = a^2 - b^2$$

$$F = 54b^2 Z_a^2$$

$$G = r_{ecef}^2 + (1 - e^2)Z_a^2 - e^2 E^2$$

$$C = \frac{e^4 F r_{ecef}^2}{G^3}$$

$$S = \sqrt[3]{1 + C + \sqrt{C^2 + 2C}}$$

$$P = \frac{F}{3(S + \frac{1}{S} + 1)^2 G^2}$$

$$Q = \sqrt{1 + 2e^4 P}$$

$$r_0 = \frac{-(Pe^2 r_{ecef})}{1 + Q} + \sqrt{\frac{a^2}{2}\left(1 + \frac{1}{Q}\right) - \frac{P(1 - e^2)Z_a^2}{Q(1 + Q)} - \frac{Pr_{ecef}^2}{2}}$$

$$U = \sqrt{(r_{ecef} - e^2 r_0)^2 + Z_a^2}$$

$$V = \sqrt{(r_{ecef} - e^2 r_0)^2 + (1 - e^2)Z_a^2} \tag{16}$$

$$Z_0 = \frac{b^2 Z_a}{aV}$$

$$\phi = \tan^{-1}\left(\frac{Z_a + e'^2 Z_0}{r_{ecef}}\right)$$

$$\lambda = \tan^{-1}\left(\frac{Y_a}{X_a}\right)$$

$$h = U\left(1 - \frac{b^2}{aV}\right)$$

where

$a = semi\text{-}major\ axis\ =\ 6378137.0\ meters$

$b = semi\text{-}minor\ axis\ =\ 6356752.3142\ meters$

$e^2 = first\ eccentricity\ squared\ =\ 6.69437999014\ x\ 10^{-3}$

$e'^2 = second\ eccentricity\ squared\ =\ 6.73949674228\ x\ 10^{-3}$

$\phi = latitude$

$\lambda = longitude$

$h = altitude$

The track is then updated by modifying following parameters:

a.   System time - updated with the TOA of the state vector report

b.   Position – updated with assembled position in WGS84 coordinates

c.   Velocity – updated with assembled velocity components

d.   NIC – updated with NIC in the state vector report

e.   State covariance matrices – updated with assembled covariance matrices

C.3.2 Inter-Source Correlation

The Inter-Source Correlation function detects when an aircraft is tracked by multiple surveillance sources and prevents the display of ghost targets on the CDTI. Inter-Source Correlation consists of the following subfunctions:

a.   Correlation between TCAS tracks and active ADS-B, ADS-R, and TIS-B tracks.

b.   Correlation between an ownship track and TIS-B tracks.

c.   Correlation between active ADS-B/ADS-R and TIS-B tracks.

C.3.2.1 TCAS to ADS-B/ADS-R/TIS-B Correlation

The TCAS to ADS-B/ADS-R/TIS-B correlation subfunction is event-driven by the reception of TCAS reports (or more precisely, initiated or updated TCAS tracks sent through the TCAS data bus). ASSAP attempts to correlate TCAS tracks with active ADS-B, ADS-R, and TIS-B tracks. Uncorrelated TCAS tracks are sent to the CDTI (via the application processor) under the assumption that they represent the only surveillance source for the target.

If Mode S addresses are available to ASSAP over the TCAS data bus (as would likely be the case in an integrated system, i.e., receiver/processor), address matching plays a key

role in TCAS to ADS-B/ADS-R/TIS-B correlation. If Mode S addresses are not available to ASSAP, the correlation technique for ATCRBS targets (described in section TBD) must be used to process all TCAS tracks. Figure C-4 contains a block diagram depicting the TCAS to ADS-B/ADS-R/TIS-B correlation function.
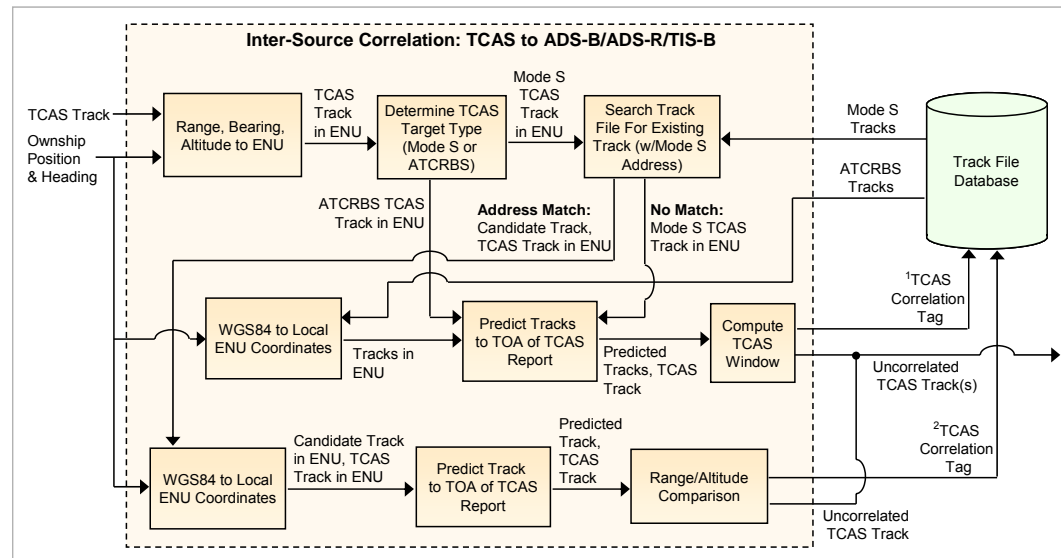

Figure C-4 **Block Diagram of the TCAS to ADS-B/ADS-R/TIS-B Correlation Function**

Note:

1. *For ATCRBS TCAS tracks (or Mode S TCAS tracks that yield no address match), a TCAS correlation tag is added to a track file (i.e., TIS-B) after repeated (i.e., 3) spatial correlations with a "complex" window; correlation history is stored in the track file.*

2. *For Mode S TCAS tracks, a TCAS correlation tag is added to a track file (i.e., ADS-B) when Mode S address matching and spatial correlation with a "simple" window succeed.*

Additionally, it is important to note that a single architecture for this function is applicable to both UAT and 1090ES ASSAP implementations. In both cases there will be track files containing Mode S identifiers (ADS-B tracks in a 1090ES implementation, ADS-R tracks in a UAT implementation).

Regardless of Mode S address availability, upon initiation or update of a TCAS track, ASSAP converts TCAS position (range, bearing, altitude) to local ENU coordinates:

$$z = z_{tcas} - z_{own}$$

$$r_{xy} = \sqrt{r^2 - z^2}$$

$$\alpha = \theta - \phi$$

$$x = r_{xy} \cos \alpha$$

$$y = r_{xy} \sin \alpha \tag{17}$$

where

$z_{tcas} =$ *TCAS altitude*

$z_{own} =$ *ownship altitude*

$r =$ *slant (TCAS) range*

$r_{xy} =$ *horizontal range*

$\theta =$ *ownship heading (measured counter-clockwise from x)*

$\phi =$ *TCAS bearing (measured clockwise from ownship heading)*

Figure C-5 provides a pictorial depiction of the coordinate conversion.

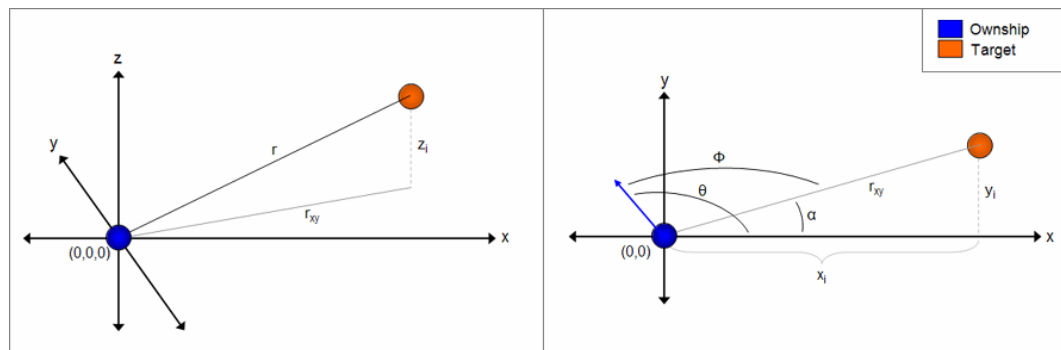**Figure C-5 TCAS Range, Bearing, and Altitude to Local ENU Conversion**

Next, ASSAP determines the TCAS target type (Mode S or ATCRBS) using the presence or absence of a 24-bit address. In the absence of a 24-bit address, ASSAP determines that the TCAS track is an ATCRBS target and uses the track number (intruder number [i:n] per ARINC 735B) as the track identifier. Target type then dictates which correlation technique is used.

C.3.2.1.1   **Mode S TCAS Track Processing**

ASSAP searches the track file database for an ADS-B/ADS-R/TIS-B track containing the same Mode S identifier as the TCAS track. If a match is found, the candidate track position is converted to local ENU coordinates with (1) and (2), then predicted to the time of applicability of the TCAS track with (3). The TCAS correlation window for Mode S targets consists of a simple range and altitude comparison:

$$r_{track} = \sqrt{\hat{x}^2 + \hat{y}^2 + \hat{z}^2}$$

$$dr = \left| r_{track} - r \right|$$

$$dz = \left| \hat{z} - z \right|$$

$$r_{threshold} = s_r 6\sigma_r$$

$$z_{threshold} = s_z 6\sigma_z$$

where

$(\hat{x}, \hat{y}, \hat{z})$ *= predicted track position in local ENU coordinates*

r_{track} *= slant range to predicted track position*

$r =$ *TCAS slant range*

$dr =$ *difference between predicted track and TCAS slant ranges*

$z =$ *TCAS relative altitude*

$dz =$ *difference between predicted track and TCAS relative altitudes*

$^1\sigma_r =$ *standard deviation of TCAS range error = 9.449 meters*

$s_r =$ *range threshold scalar*

$r_{threshold} =$ *threshold for difference between predicted track and TCAS slant ranges*

$^2\sigma_z =$ *standard deviation of TCAS altitude error = 3.889 meters*

$s_z =$ *altitude threshold scalar*

$z_{threshold} =$ *threshold for difference between predicted track and TCAS relative altitudes*

Note:

1. *The range error standard deviation of 9.449 meters is derived from a 95% bound of 0.01 NM.*

2. *The altitude error standard deviation of 3.889 meters is derived from a 95% bound of 25 feet.*

Table C-1 contains values for sr and sz that produced a perfect probability of correlation using TCAS and 1090ES ADS-B flight test data recorded at the FAA Technical Center (July 2007).

**Table C-1 Optimal Scalar Values for the
Mode S TCAS Correlation Window**

Scalar	Optimal Value
sr	10.976
sz	4.900

If dr ≤ rthreshold and dz ≤ zthreshold , the track file (ADS-B, ADS-R, or TIS-B) is tagged as a TCAS equipped target (i.e., a field denoted "TCAS_tag" is set to 1). If spatial correlation fails, the uncorrelated TCAS track is forwarded to the application processor.

If a matching Mode S address cannot be found in the track file database, ASSAP attempts to correlate the Mode S TCAS track with ATCRBS targets using the technique described in the next section. This is intended to deal with cases where multiple surveillance tracks for a single aircraft will have different identifiers (i.e., TCAS with Mode S address and TIS-B with a ground-assigned address).

C.3.2.1.2   ATCRBS (or Unmatched Mode S) TCAS Track Processing

For all tracks in the track file database without Mode S identifiers, track position is converted to local ENU coordinates with (1) and (2), then predicted to the time of applicability of the TCAS track with (3). Each track file is compared to the TCAS track with a dynamic correlation window that changes size to account for a number of error sources. The dynamic window consists of horizontal (core and buffer) and vertical components. The horizontal window's core (depicted in Figure C-6) is a trapezoid based on potential range and bearing error in the TCAS track and error in the calculation of two-dimensional range.
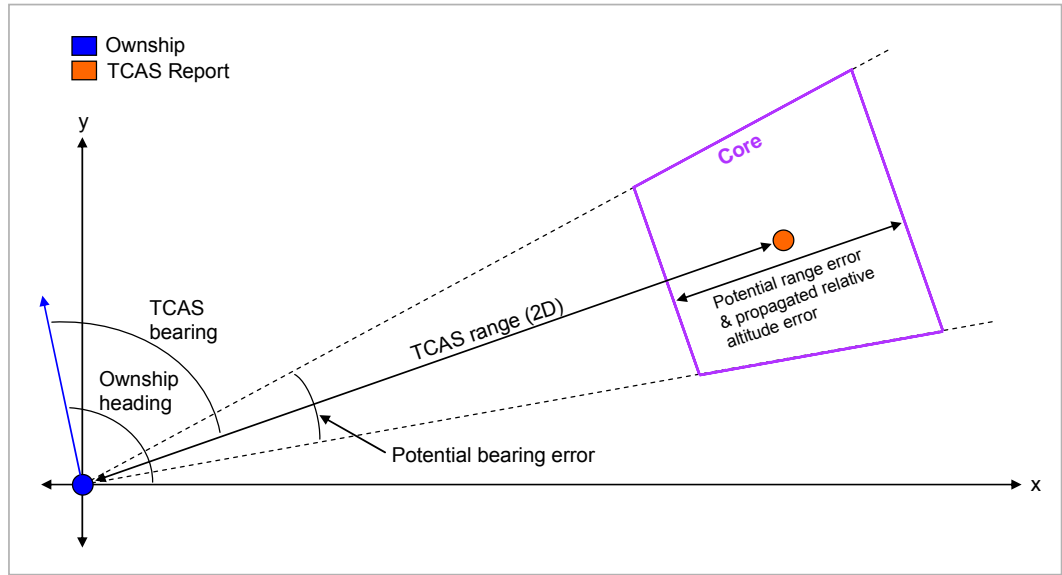
<u>Figure C-6</u> Dynamic TCAS Correlation Window – Horizontal Core

The horizontal core of the dynamic TCAS window is defined as follows:

$$L = 2s_l(6\sigma_r)$$

$$\beta = 6\sigma_b$$

$$p_1 = \left[\left(r_{xy} - \frac{L}{2}\right)\cos\alpha + \left(r_{xy} - \frac{L}{2}\right)\tan\beta\cos\left(\alpha + \frac{\pi}{2}\right), \left(r_{xy} - \frac{L}{2}\right)\sin\alpha + \left(r_{xy} - \frac{L}{2}\right)\tan\beta\sin\left(\alpha + \frac{\pi}{2}\right)\right]$$

$$p_2 = \left[\left(r_{xy} + \frac{L}{2}\right)\cos\alpha + \left(r_{xy} + \frac{L}{2}\right)\tan\beta\cos\left(\alpha + \frac{\pi}{2}\right), \left(r_{xy} + \frac{L}{2}\right)\sin\alpha + \left(r_{xy} + \frac{L}{2}\right)\tan\beta\sin\left(\alpha + \frac{\pi}{2}\right)\right]$$

$$p_3 = \left[\left(r_{xy} + \frac{L}{2}\right)\cos\alpha + \left(r_{xy} + \frac{L}{2}\right)\tan\beta\cos\left(\alpha + \frac{3\pi}{2}\right), \left(r_{xy} + \frac{L}{2}\right)\sin\alpha + \left(r_{xy} + \frac{L}{2}\right)\tan\beta\sin\left(\alpha + \frac{3\pi}{2}\right)\right]$$

$$p_4 = \left[\left(r_{xy} - \frac{L}{2}\right)\cos\alpha + \left(r_{xy} - \frac{L}{2}\right)\tan\beta\cos\left(\alpha + \frac{3\pi}{2}\right), \left(r_{xy} - \frac{L}{2}\right)\sin\alpha + \left(r_{xy} - \frac{L}{2}\right)\tan\beta\sin\left(\alpha + \frac{3\pi}{2}\right)\right]$$

where

s_l = *adaptable length scalar.*

[1]σ_b = *standard deviation of bearing error = 6.67 degrees = 0.1164 radians.*

p_1, p_2, p_3, p_4 = *points that define the horizontal core (as illustrated by Figure C-7).*

*Note: The bearing error standard deviation of 6.67 degrees is the value observed at the
FAA Technical Center in July 2007 during flight tests involving high turn
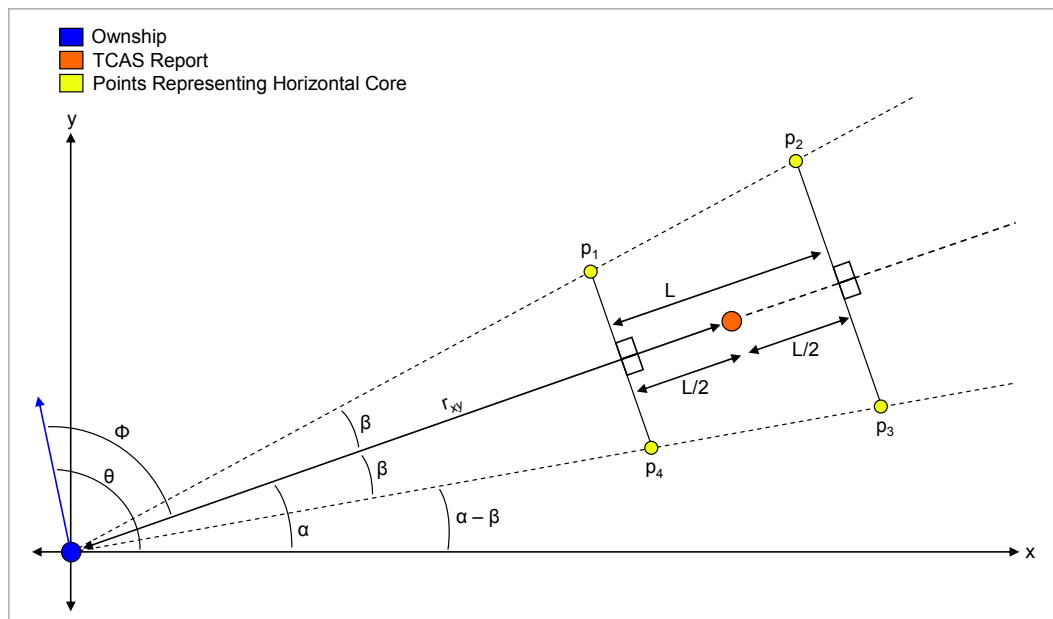dynamics.*

Figure C-7 **Dynamic TCAS Correlation Window – Points Representing the
Horizontal Core**

Table C-2 contains an optimal value for sl identified through simulation testing.

Table C-2 **Optimal Length Scalar for the
Dynamic TCAS Correlation Window**

Scalar	Optimal Value
sl	32.667

*Note: In the case where address is not a viable correlation parameter, it is important to
note that the word optimal should be interpreted differently. A very large length
scalar (and hence large window) will increase the probability of correlation,
however, this includes the potential for miscorrelation. Therefore the length
scalar should be large enough to achieve a high correlation rate, but small
enough to minimize the probability of miscorrelation. The value listed in Table
C-2 translates to a core length of 3704 meters (2 NM). This is small enough to
reduce the risk of miscorrelation (due to separation standards), yet large enough
to achieve a high correlation rate (97.442% with TCAS and TIS-B data obtained
from flight tests at the FAA Technical Center).*

The horizontal window's buffer (depicted in Figure C-8) is a 12-sided polygon based on
track horizontal position error and prediction error introduced when tracks are
extrapolated to the TOA of the TCAS report. The buffer is an estimate of the shape that

would be formed when a circle representing track position uncertainty is moved completely around the core, with the center of the circle remaining on the border of the trapezoid. Buffer widths can change dramatically depending on the track being examined.

For tracks with poor NACp values (i.e., 4), the buffer will be large due to potential position error. If the time difference between the TCAS update and track update is significant (i.e., 10 seconds), the buffer will be large due to potential prediction error.
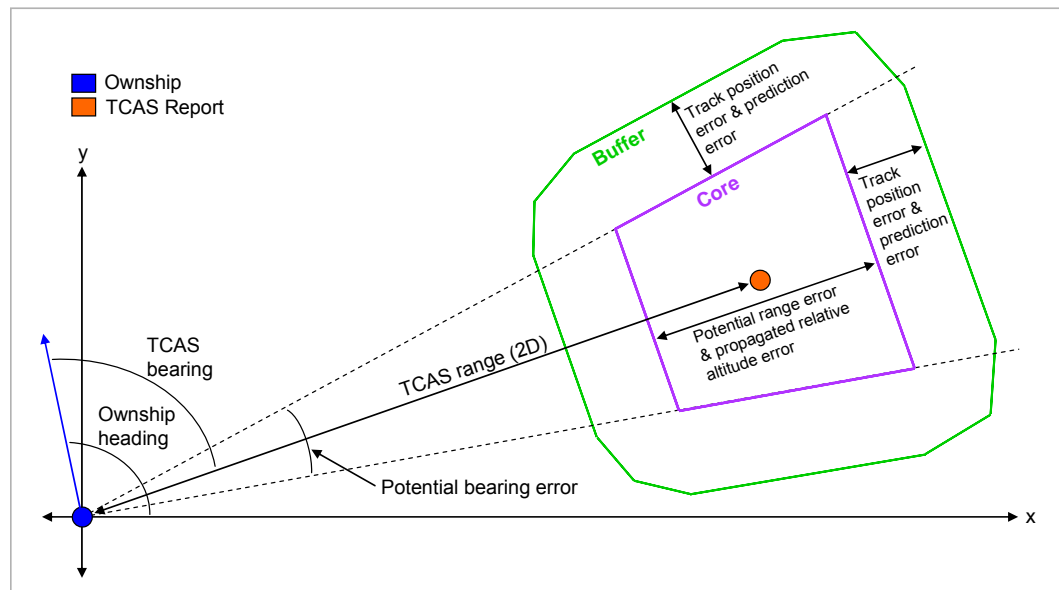
Figure C-8 Dynamic TCAS Correlation Window – Horizontal Buffer

First, the width of the buffer is defined as follows:

$$w = 3\sigma_{epu} + v(dt)$$

where

σ_{epu} = *is standard deviation of track position uncertainty (derived from NACp).*

v = *track speed (along-track horizontal velocity).*

dt = *time difference between the TCAS track TOA and track file TOA.*

The buffer (and hence the horizontal window) is then defined by rotating radii (equal to the buffer width) about the points that make up the core:

$$\mu = \frac{\pi - 2\beta}{4}$$

$$\gamma = \frac{\pi + 2\beta}{4}$$

$$q_1 = p_1 + \left[w\cos\left(\alpha + \beta + \frac{\pi}{2} + 2\mu \right), \, w\sin\left(\alpha + \beta + \frac{\pi}{2} + 2\mu \right) \right]$$

$$q_2 = p_1 + \left[w\cos\left(\alpha + \beta + \frac{\pi}{2} + \mu \right), \, w\sin\left(\alpha + \beta + \frac{\pi}{2} + \mu \right) \right]$$

$$q_3 = p_1 + \left[w\cos\left(\alpha + \beta + \frac{\pi}{2} \right), \, w\sin\left(\alpha + \beta + \frac{\pi}{2} \right) \right]$$

$$q_4 = p_2 + \left[w\cos(\alpha + 2\gamma), \, w\sin(\alpha + 2\gamma) \right]$$

$$q_5 = p_2 + \left[w\cos(\alpha + \gamma), \, w\sin(\alpha + \gamma) \right]$$

$$q_6 = p_2 + \left[w\cos\alpha, \, w\sin\alpha \right]$$

$$q_7 = p_3 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} + 2\gamma \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} + 2\gamma \right) \right]$$

$$q_8 = p_3 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} + \gamma \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} + \gamma \right) \right]$$

$$q_9 = p_3 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} \right) \right]$$

$$q_{10} = p_4 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} \right) \right]$$

$$q_{11} = p_4 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} - \mu \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} - \mu \right) \right]$$

$$q_{12} = p_4 + \left[w\cos\left(\alpha - \beta - \frac{\pi}{2} - 2\mu \right), \, w\sin\left(\alpha - \beta - \frac{\pi}{2} - 2\mu \right) \right]$$

where

μ, γ = angles used to rotate radii (buffer width) about points that make up core.

$q_1, q_2, \ldots q_{12}$ = points that define the horizontal buffer and horizontal window (as illustrated by Figure C-9).
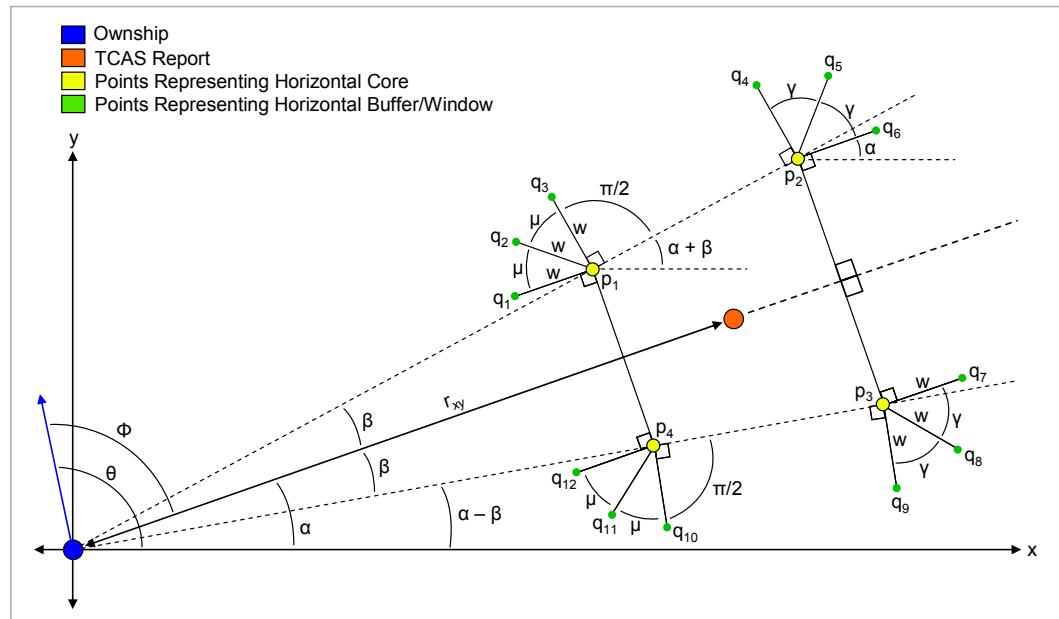
**Figure C-9 Dynamic TCAS Correlation Window – Points Representing the
Horizontal Buffer/Window**

APPENDIX D

TBD

APPENDIX D A CD ALGORITHM

D.1   Introduction

TBD.

APPENDIX E

CONFLICT DETECTION (CD)

APPENDIX E CONFLICT DETECTION (CD)

E.1   Introduction

The core function of the Conflict Detection (CD) application is the issuing of conflict alerts based on two sets of detection thresholds.

E.2   Operational Performance Assessment

This section describes the purpose, method, and results of the operational performance assessment for the Conflict Detection application.

E.2.1   Purpose

The goals of the CD application are to enhance safety and to enhance airborne traffic awareness. The CD application detects conflicts based on predicted flight paths of aircraft.

For the CD application, there are two sets of alerting criteria: the Collision Avoidance Zone (CAZ) and the Collision Detection Zone (CDZ). An alert is issued by a CD application if the predicted aircraft positions violate either of the two zones. CAZ and CDZ are defined in terms of the following parameters: horizontal size, vertical size. An alert time will be used to determine when the alert should go off. The separation parameters vary with the domain of operations which include GA traffic pattern operations, terminal area operations, and high altitude en route operations.

E.2.2   Method

In this sub-section, we describe the method that we used to establish the requirements. We describe the CD algorithm, the data that we used in simulation, metrics, and the trial-and-error method that we used to establish the requirements. The following items are described:

a.   A CD algorithm.

b.   Data used to test the algorithms.

c.   Metrics used to rate the algorithms.

E.2.2.1   A CD Algorithm

We established the requirements on the parameters for the CD application by using Monte Carlo simulation. A Conflict Detection algorithm was used in the simulation. The algorithm calculates the predicted horizontal and vertical separations of the aircraft pair based on the current reported positions and velocity vectors of the two aircraft. The

reported positions and velocity vectors contain error terms caused by underlying navigation systems among other things. NACp and NACv values were used to generate such error terms in Monte Carlo simulation. The error terms were then added to the true positions and true velocity vectors to form the reported positions and velocity vectors.

The CD alerts are based on predicted separation. The predicted separation is compared with the CAZ (or CDZ) alert thresholds. The algorithm issues an alert if it predicts a violation of the horizontal separation threshold and the vertical separation threshold within the alert time.

The CD algorithm uses rigid criteria to determine whether there will be a violation of the CAZ (or CDZ). Even if the predicted separation is very close to (but greater than) the separation thresholds, the CD algorithm determines that there will be no violation of the CAZ (or CDZ).

E.2.2.1.1 CAZ Algorithm

The CAZ algorithm depends upon difference in position and speed between Ownship and the target vehicle, defined in (1). The subscript "i" in (1) refers to target and the subscript "o" refers to Ownship.

Differentiating (1) with respect to time t, we obtain the time to closest point of approach (CPA):

$$t_{CPA} = -\frac{(dx)(d\dot{x}) + (dy)(d\dot{y})}{(d\dot{x})^2 + (d\dot{y})^2} \tag{1}$$

The horizontal miss distance at t_{CPA} is

$$hmd = \frac{\left|(dx)(d\dot{y}) - (dy)(d\dot{x})\right|}{\sqrt{(d\dot{x})^2 + (d\dot{y})^2}} \tag{2}$$

The height difference at t_{CPA} is

$$dh_{TCPA} = (h_o - h_i) + t_{CPA}(\dot{h}_o - \dot{h}_i) \tag{3}$$

If (hmd < T_{hmd} and dh_{TCPA} < T_h and t_{CPA} < T_t) then issue CAZ alert, where T_{hmd}, T_h, and T_t are the horizontal, vertical and time alert thresholds, respectively.

E.2.2.1.2 CDZ Algorithm

Let Ch be the horizontal CDZ threshold. Then the horizontal CDZ is violated if $\rho(t) <$ Ch.

That is equivalent to

$$t_{CPA} - \sqrt{\frac{c_h^2 - (hmd)^2}{(d\dot{x})^2 + (d\dot{y})^2}} < t < t_{CPA} + \sqrt{\frac{c_h^2 - (hmd)^2}{(d\dot{x})^2 + (d\dot{y})^2}}$$

(4)

Let $\Delta h(t) = (h_0 - h_i) + t(\dot{h}_0 - \dot{h}_i)$ and let Cv be the vertical CDZ threshold. Then the vertical CDZ is violated if $\Delta h(t) < C_v$.

That is equivalent to

$$t > \frac{C_v - (h_o - h_i)}{\dot{h}_o - \dot{h}_i} \text{ if } h_o - h_i > 0 \text{ or } t < \frac{C_v - (h_o - h_i)}{\dot{h}_o - \dot{h}_i} \text{ if } h_o - h_i < 0$$

(5)

If the time intervals defined in (3) and (4) overlap, then issue a CDZ alert.

E.2.2.2   **Data**

For terminal and en route operation scenarios, we used real operational data in the form of ARTS data files in Monte Carlo simulation. The ARTS data files were used in operational evaluations of TCAS [1] when TCAS was developed. They were recorded at 11 facilities and contain about 4000 encounters. For terminal and en route operation CAZ simulations, trajectories were offset in the simulation to induce collision in order to ensure sufficient sample sizes. For GA traffic pattern operations, representative GA scenarios developed by RTCA SC 186 WG 1 were used.

For terminal operations, ARTS data for layers 1, 2, and 3 were used in the simulation. For en route operations, ARTS data for layers 4 and 5 are used. Layers 1, 2, 3, 4 and 5 are defined in terms of altitude (see Table E-1).

Table E-1 Definition of Layers

Layer	Altitude
1	1450 ft AGL – 2350 ft AGL
2	2350 ft AGL – 5000 ft MSL
3	5000 ft MSL – 10000 ft MSL
4	10000 ft MSL – 20000 ft MSL
5	20000 ft MSL – 41000 ft MSL

E.2.2.3   Metrics

The following metrics were used to measure the performance of the CD application:

Average duration of false alerts per non-violation encounter.

Average number of missed detections per violation encounter.

A "non-violation encounter" is an encounter between two aircraft where there is no violation of CAZ (or CDZ). On the other hand, a "violation encounter" is an encounter between two aircraft where there is at least one violation of CAZ (or CDZ).

The duration of false alerts and the number of missed detections are determined as follows. The simulation records two sets of positions of aircraft: the true positions and the reported positions. The true positions of aircraft come directly from the ARTS data files or GA pattern scenario files. The reported positions of aircraft are generated by adding error terms to the true positions. The error terms are caused by navigation errors and so on. If the true positions of the aircraft indicate that there is no penetration of the CAZ (or CDZ) (a non-violation encounter) but the CD algorithm predicts a penetration and issues an alert, then the alert is considered a false alert. The sum of the time span between the start and the end of each false alert in an encounter is the duration of false alert for that encounter. On the other hand, if the true positions of the aircraft indicate there is a penetration of the CAZ (or CDZ) (a violation encounter) and the CD algorithm did not issue an alert before penetration occurs, then there is a missed detection.

APPENDIX F

METRICS USED TO RATE THE ALGORITHMS

APPENDIX F ENHANCED VISUAL APPROACH (EVAPP)

F.1   Introduction

The core function of the Enhanced Visual Approach (EVApp) application is the calculation of range and closure rate between Ownship and a target selected on the CDTI. This appendix presents an analytical comparison of sample algorithms for the calculation of closure rate.

F.2   Operational Performance Assessment

This section describes the purpose, method, and results of the operational performance assessment for the Enhanced Visual Approach application.

F.2.1   Purpose

The primary goal of the EVApp application is to allow the flight crew to detect and track the preceding aircraft more effectively. The purpose of this operational performance assessment is to identify an algorithm that produces an accurate closure rate with information available to Ownship.

F.2.2   Method

In this subsection, the following items are described:

a.   Two closure rate algorithms.

b.   Data used to test the algorithms.

c.   Metrics used to rate the algorithms.

F.2.2.1   Closure Rate Algorithms

Closure rate is defined as the change in slant range between Ownship and a target vehicle with respect to time. ADS-B/TIS-B reports limit potential approaches to a position-based algorithm or position and velocity-based algorithm. The algorithms presented here use the Cartesian East North Up (ENU) coordinate system; WGS-84 positions are converted to ENU.

F.2.2.1.1   Position-Based Algorithm for Closure Rate

The position-based algorithm for closure rate solely depends upon difference in position between Ownship and the target vehicle, defined in (1). The subscript "t" in (1) refers to target and the subscript "o" refers to Ownship. Difference in velocity is defined as a function of difference in position and time (2). Closure rate, cr, is defined in (3). The

negative sign in (3) is due to convention; a positive closure rate represents decreasing range and a negative closure rate represents increasing range.

$$dx = x_t - x_o$$
$$dy = y_t - y_o$$
$$dz = z_t - z_o \tag{1}$$

$$d\dot{x} = \frac{\Delta dx}{\Delta t} = \frac{dx_2 - dx_1}{t_2 - t_1}$$
$$d\dot{y} = \frac{\Delta dy}{\Delta t} = \frac{dy_2 - dy_1}{t_2 - t_1}$$
$$d\dot{z} = \frac{\Delta dz}{\Delta t} = \frac{dz_2 - dz_1}{t_2 - t_1} \tag{2}$$

$$cr = -\frac{dx(d\dot{x}) + dy(d\dot{y}) + dz(d\dot{z})}{\sqrt{dx^2 + dy^2 + dz^2}} \tag{3}$$

F.2.2.1.2 Position and Velocity-Based Algorithm for Closure Rate

The position and velocity-based algorithm for closure rate depends upon difference in position and difference in velocity between Ownship and the target vehicle. Equations (1) and (3) remain valid, however, (2) is rewritten as (4) using velocities for Ownship and target aircraft.

$$d\dot{x} = v_{x_t} - v_{x_o}$$
$$d\dot{y} = v_{y_t} - v_{y_o}$$
$$d\dot{z} = v_{z_t} - v_{z_o} \tag{4}$$

F.2.2.2 Data

A terminal scenario was generated to test the closure rate algorithms. Truth trajectories for two large aircraft, a leader and a follower, were generated using the following specifications:

a. A final approach distance of 10 NM (18520 m).

b. A descent angle of three degrees.

c. An in-trail separation distance of 2.5 NM (4630 m).

d. Constant, nominal speeds of 150 knots (77.16 m/s).

To simulate information available to Ownship, state data was sampled at 1 Hz and noise was added to positions and velocities with random variables. Position and velocity noise for both Ownship and target aircraft corresponded to the minimum requirements of the EVApp application (NACp = 7, NACv = 1).

To represent the worst case scenario, there was no serial correlation between errors in consecutive states for either aircraft. Ownship was set as the follower. Figure F-1 contains a visualization of this scenario as it would appear on the CDTI.
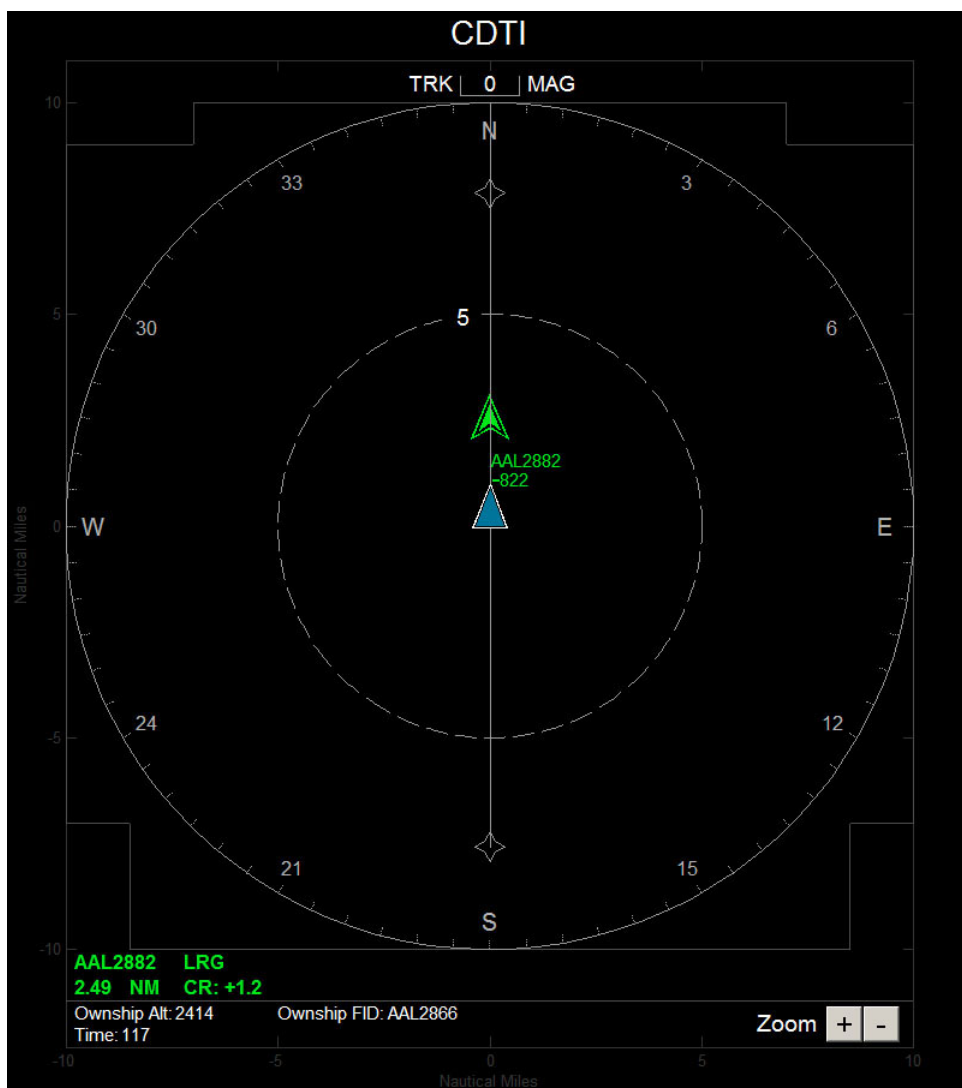

Figure F-1 Depiction of the Scenario Used to Test Closure Rate Algorithms for EVApp

F.2.2.3   **Metrics**

The metric used to compare closure rate algorithms is the difference between true and observed closure rate (i.e., error). Given that the terminal scenario was set up with constant, equal velocities for both aircraft, true closure rate any point in time is zero. Thus in this case, the observed closure rate represents the difference between true and observed values. The final approach scenario was repeated 10000 times and prediction intervals were calculated for closure rate error produced by both algorithms.

F.2.3   **Results**

Table C-3 contains 95% prediction intervals for closure rate error produced by the two algorithms presented in this appendix.

Table C-3 95% Prediction Intervals for Closure Rate Error Produced by Position-based and Position and Velocity-based Algorithms

Closure Rate Algorithm	95% PI Bounds for Closure Rate Error (knots)
Position-Based	±507.365
Position and Velocity-Based	±19.213

Since this analysis focused on the worst case scenario with minimal state data accuracy, any permutation of the state data vector available to EVApp will produce closure rate error within the bounds listed in Table C-3. The accuracy of the presented closure rate algorithms can be summarized as follows:

a.   A closure rate algorithm based solely upon difference in position between Ownship and a target vehicle will produce a closure rate within ±507.365 knots (260.988 m/s) of the true value 95% of the time.

b.   A closure rate algorithm based upon differences in position and velocity between Ownship and a target vehicle will produce a closure rate within ±19.213 knots (9.883 m/s) of the true value 95% of the time.

The dramatic difference in algorithm performance is due to the effect of position error. In the position-based algorithm, current and previous positions are factored into the equations for difference in velocity, which is evident when (2) is rewritten as (5).

$$d\dot{x} = \frac{dx_2 - dx_1}{t_2 - t_1} = \frac{\left(x_{t_2} - x_{o_2}\right) - \left(x_{t_1} - x_{o_1}\right)}{t_2 - t_1}$$

$$d\dot{y} = \frac{dy_2 - dy_1}{t_2 - t_1} = \frac{\left(y_{t_2} - y_{o_2}\right) - \left(y_{t_1} - y_{o_1}\right)}{t_2 - t_1} \tag{5}$$

$$d\dot{z} = \frac{dz_2 - dz_1}{t_2 - t_1} = \frac{\left(z_{t_2} - z_{o_2}\right) - \left(z_{t_1} - z_{o_1}\right)}{t_2 - t_1}$$

As a result, there are twenty-four position variables in the position-based closure rate formula, as opposed to twelve in the position/velocity-based formula. The multiplication of variables further degrades the accuracy of the position-based formula.

It is concluded that a position/velocity-based algorithm for closure rate is the most accurate approach. If a position-based algorithm is considered, it is recommended that an appropriate filter is added to dampen the effect of position error. The potential error in a position-based closure rate is nearly half as large as the maximum possible closure rate between two commercial aircraft

APPENDIX G

TRACEABILITY MATRIX TO DO-289 ASA MASPS

APPENDIX G TRACEABILITY MATRIX

APPENDIX H

SERVICE STATUS

APPENDIX H PROVIDING THE PILOT AN INDICATION OF TIS-B SERVICE STATUS

In certain TIS-B service areas, the FAA will be able to provide a relatively comprehensive traffic information picture to pilots via TIS-B. For this reason, it is highly desirable for the TIS-B system to support a *TIS-B service status* indication so that pilots will know when the traffic picture in the immediate proximity can be expected to be reasonably complete and when there should be no such expectation. The FAA specification requires the Service Provider to support this service status indication for users of the UAT data link[1]. This section describes the concept along with recommended procedures for the avionics to provide the service status indication to the pilot. No similar expectation of a relatively complete traffic picture can exist for ADS-BADS-R (for some time at least) due to its dependence on ADS-B equipage.

Note: *The TIS-B service will not provide information on traffic that is not visible to the ground surveillance system, i.e., unequipped aircraft.*

H.1   TIS-B Signaling

TIS-B messages are not needed to represent traffic that is ADS-B equipped since it is assumed that ADS-B equipped traffic will be adequately represented via direct air-air ADS-B reception. However, the TIS-B ground system will uplink TIS-B signaling information for ADS-B equipped aircraft—at a low average rate—for the purpose of providing a service status indication. The only signal type defined at this time will be referred to as a "heartbeat" signal. The heartbeat signal is provided periodically as a positive indication to the TIS-B customer that TIS-B service is *available*. Conversely, lack of any heartbeat signal for a certain interval—referred to as the HEARTBEAT_TIMEOUT interval—indicates that service is *not available*.

The heartbeat signal is conveyed in the UAT Ground Uplink message as a list of TIS-B customer addresses to which the signal pertains. The frame type identifier "15" is used for this purpose. Four bytes are used to represent each heartbeat signal and individual heartbeat signals are packed sequentially for uplink into the Frame Data portion of the Information Frame as described in Section 2.2.3.3. The format of an individual TIS-B signal is shown in Table H-1. A single Ground Uplink message could convey a maximum of 105 TIS-B signals if all payload of the Ground Uplink message is used for signaling. This assumes all 105 signals were packed into a single Information Frame.

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[1] 1090 ES has no facility to convey the signaling information similar to the method described here for UAT. Another, technique for supporting a similar service status indication for the pilot are proposed for TIS-B over 1090 ES and may be implemented at a later time.

Table H-1 Format of Individual TIS-B Signal

Transmn order	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
1st			Reserved		Sig.	Address Qualifier		
2nd	(MSB)A1	A2	A3	. . .				
3rd	Address							
4th					. . .	A22	A23	A24(LSB)

.
.

When the SIGNAL TYPE bit is "1", the signal is a heartbeat signal: service is available. When the SIGNAL TYPE bit is "0", the signal is a "goodbye" signal: service is not available. Initially, the ground system will provide only the "heartbeat" signal. The avionics processing description below uses only the heartbeat signal only.

The presence of a heartbeat signal for a TIS-B customer indicates that TIS-B service should be available for traffic in the immediate proximity. Upon entry into airspace where the TIS-B system has both surveillance coverage AND UAT ground station coverage (i.e., ADS-B downlinks received), heartbeat messages are transmitted. To aid the TIS-B customer to initially acquire their heartbeat messages, the transmission rate may initially be high for a short period (e.g., a rate similar to TIS-B message rate used to represent traffic). Subsequently, the rate is decreased to a low rate used only to "hold up" the service available indication. This low rate would be established to ensure at least one heartbeat reception by the TIS-B customer every HEARTBEAT_TIMEOUT seconds. It is recommended that avionics treat the HEARTBEAT_TIMEOUT as a parameter with a factory default of [60] seconds.

Note: As experience is gained with the TIS-B service, it may be desirable to use a timeout value other than the default. In the future, it is expected that the TIS-B function will broadcast a HEARTBEAT_TIMEOUT value that would override the default.

H.2   Avionics Processing to Determine TIS-B Service Status

It is recommended that at least the two TIS-B service status indications listed in Table H-2 are supported.

Table H-2 TIS-B Service Status Indications

TIS-B Service Status Indication	Meaning
"AVAILABLE"*	TIS-B customer can expect updates on traffic in the immediate proximity with reasonable confidence.
"NO SVC"*	TIS-B customer should not expect updates on traffic in the immediate proximity

* These are example annunciations only; any equivalent annunciations that convey the intended meaning may be used

Figure H-1 illustrates the conditions for both of the service status indications relative to the TIS-B Service Volume. The term "TIS-B Service Volume" as used in this document represents the intersection of the *Surveillance Coverage Volume* and the UAT *Ground Station Service Volume* where these latter terms in italics are described in [TIS-B MASPS].
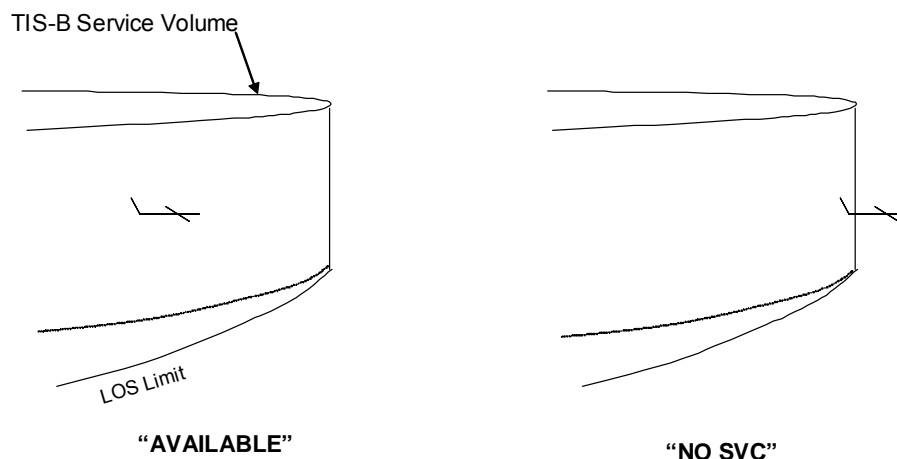
TIS-B Service Volume

"AVAILABLE"   "NO SVC"

Figure H-1 Illustration of TIS-B Service Status

While Figure H-1 shows the customer aircraft exiting service through a lateral boundary in the TIS-B service volume, a more typical case is likely to be when the customer aircraft descends through the line-of-sight floor of the TIS-B service volume. This could be a common situation when a UAT ground station is sited at an airport location where the nearest surveillance radar is some distance away. Figure H-2 shows this case.
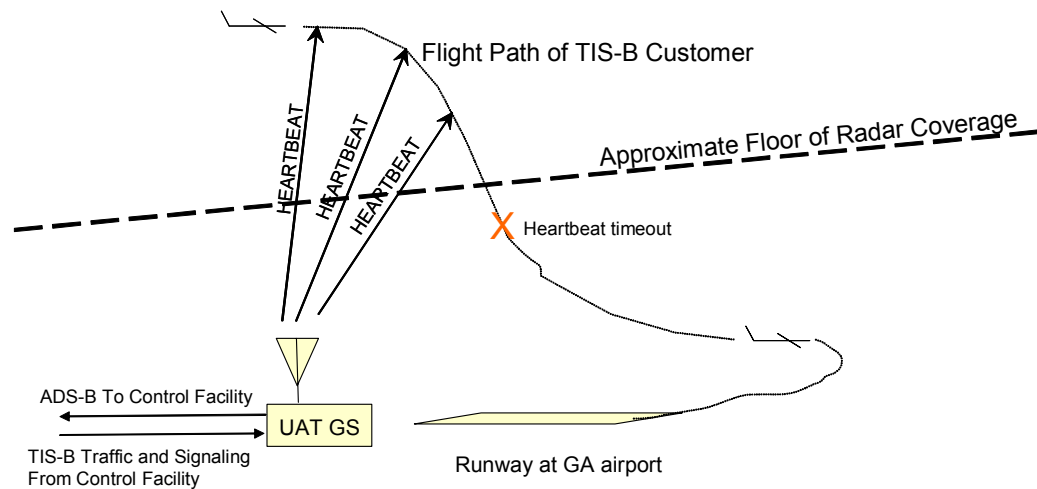
Figure H-2 TIS-B Customer Leaving Service Through Floor of Radar Coverage

Most of the processing to support the TIS-B service status indication is performed by the TIS-B ground system. Figure H-3 shows a logic flowchart that would provide the recommended status indications.
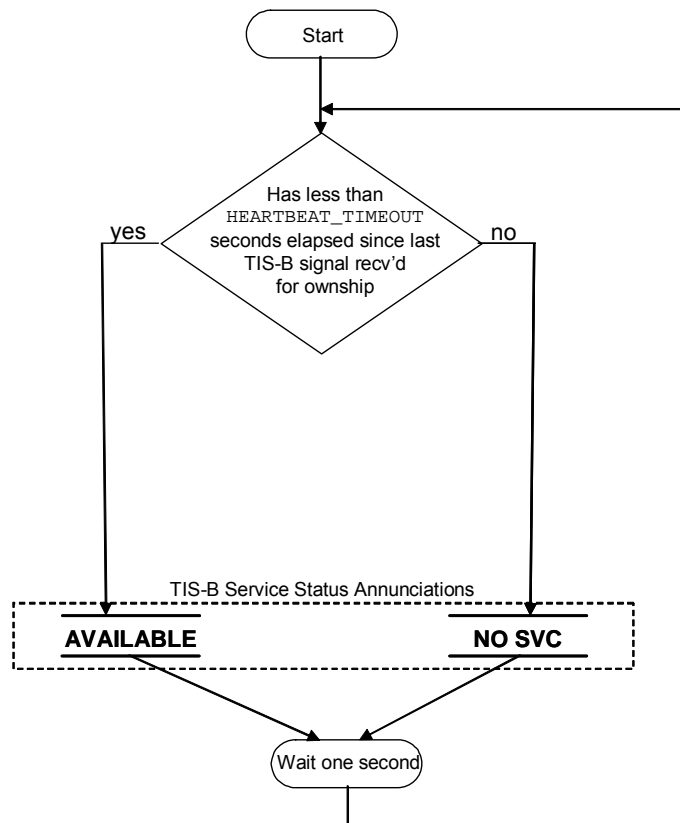

Figure H-3 Avionics Processing Logic to Support the TIS-B Service Status Indication

H.3   **Additional Points Relative to TIS-B Service Status**

This service status approach is designed to provide high confidence of service for those that receive the "AVAILABLE" indication. This is because the TIS-B heartbeat messages provide confirmation of operation for the entire TIS-B system for the customer's immediate airspace environment. Even in cases where no traffic is visible on the display, the pilot has reasonable confidence the TIS-B system has no traffic in the customer's immediate proximity to depict since the heartbeat message is being provided. On the other hand, a "NO SVC" indication could result in the pilot still seeing traffic on the display. This could be for either of three reasons: 1) traffic is due to ADS-B air-air message reception not subject to the service status indication, 2) traffic is due to TIS-B message reception, but for traffic not in the immediate proximity of the TIS-B customer aircraft, 3) the TIS-B customer is skirting the edge of the TIS-B service volume resulting in possible intermittent depiction of proximate traffic.

Providing a TIS-B service status indication can be fully supported only for TIS-B customers who are also ADS-B participants.